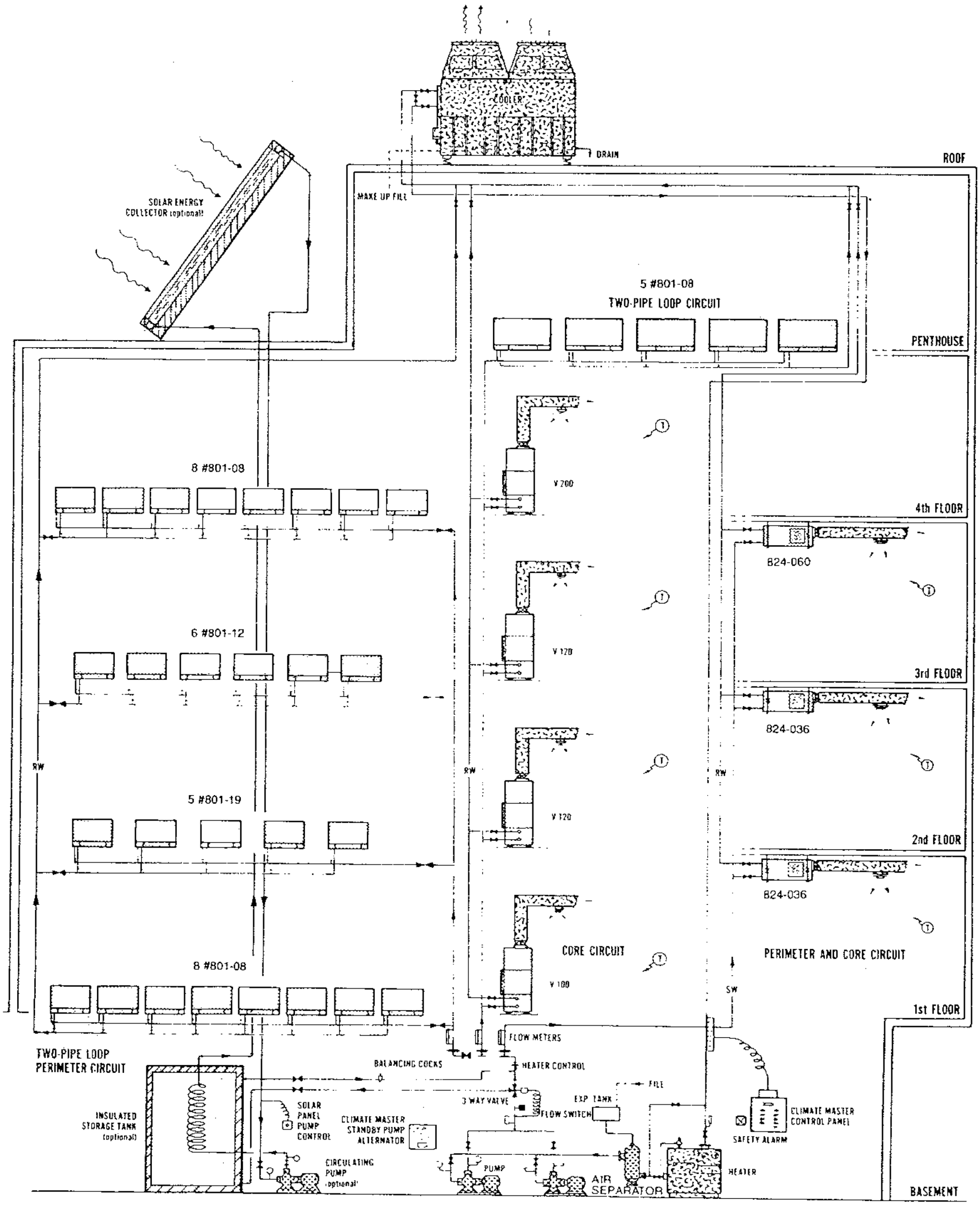
ENGINEERING HANDBOOK

ClimateMaster®

WATER-SOURCE HEAT PUMP HEAT RECOVERY SYSTEMS



Foreword

This manual is intended to provide the engineer with detailed information on applications and methods for designing water source heat pump heat recovery systems. The material is organized to help in planning a logical, step-by-step design of this kind of system.

We have chosen an office building as "criteria." The application of the system to other types of structures will be similar, with varying inputs depending on location and governing codes. It will be necessary to refer to the Climate Master engineering application catalogs for definitive data from curves and charts for specific units.

It is impossible to cover all variables associated with the application and design of an air conditioning and heating system. However, this guide plus data from ASHRAE Handbooks, ASHRAE Standard 90-75, ARI, and other sources, will provide a basis for understanding the principle, application and system approach for a water-source heat pump heat recovery system.

Specifically, the step-by-step approach will cover the following:

1. Explanation of the system
2. Application and economics
3. Unit configuration
4. Analysis of a building
5. Heating and cooling loads
6. Unit selection
7. Ducting
8. Pipe sizing
9. Heat rejector selection
10. Heater selection
11. Pumping
12. Controls
13. Start-up procedures

In addition, information will be provided on the basis of which the Heat Recovery System may be evaluated for performance, for first cost, and for operating and maintenance costs. A case history of an installed project is included. This project was set up with multiple meters in order to provide authentic operating cost information, and the results are shown in the case history.

As the state of the art grows, this manual will be revised and updated from time to time to incorporate the latest available information and data. Therefore, this data and specifications are subject to change without notice.

Continued contribution by the staff at Climate Master and its customers will prove invaluable in the future management of energy.

Contents

I. The Heat Pump Heat Recovery System

The Heat Pump Heat Recovery System utilizes energies that once were thrown away or not used. It consists of packaged refrigeration reverse-cycle units interconnected by a water circulating loop which is supplied with means of rejecting excess heat or adding heat when required.

In most structures, there is constant energy that previously was wasted or unused which is now recoverable. These energy sources within a structure are:

Lights

The light energy in most structures varies from 3 watts to 6 watts per square foot. Through the air circulation of the heat recovery system, this heat can be absorbed and utilized in areas of the building during the heating season where heat may be required.

People

People give off heat energy ranging from 300 to 500 BTU per person depending upon their activity. By the same process, this heat can be recovered and reused.

Machinery

Machinery normally used to some degree in most structures, such as motors, stoves, ovens, compressors, transformer vaults, telephone equipment and elevator machinery, give off heat. Through the air circulation of the heat recovery system, this heat can be absorbed and utilized where needed.

Computers

An extremely large heat source is the computer. In some buildings, computers which operate continuously can provide almost enough heat to overcome the heat losses of the buildings. The computer coolers are connected to the same heat recovery water loop. Thus, heat rejected to this water becomes usable heat for the building.

Solar Gain

Solar gain on a building is a variable, but on those days when it occurs, the flexibility of the heat recovery system allows this solar energy to be absorbed and transferred to the areas requiring heat. Design orientation of the building can be accomplished to take the greatest advantage of solar gain reuse.

Domestic Water

Heat energy from the heat recovery system can be used to heat domestic water, thus using rejected heat to reduce primary energy usage in heating domestic hot water and in preheating water for recreational facilities such as swimming pools and ice skating areas.

Industrial Ventilation

Heat from various exhaust systems can be incorporated into the Heat Recovery System to reduce make-up air heating requirements and, with various economizer cycles, can add to overall efficiencies.

There can be many other internal heat sources within a structure, but these are the major ones. All such constant heat sources should be calculated, because they can be absorbed with the heat recovery system.

A typical building has a perimeter load affected directly by its exposure to variable outdoor weather conditions and a core load that is less directly affected by outdoor conditions.

In **Figure 1**, four possible examples are cited to which the complete system could be exposed.

If the entire structure requires heat, then both the perimeter and core are on the heat cycle. When this occurs, heat will be absorbed from the water by the individual heat pumps; and this heat must be added back into the circulating water by means of a heater — utilizing oil, gas, or electricity as a heat source.

If the entire structure requires cooling, the heat from the structure will be added to the water by the individual heat pumps; and this heat must be rejected by means of a cooler — either closed-circuit, open tower, heat exchanger, well water or ponds.

At times, the core is being cooled, thus adding heat to the water, while simultaneously the perimeter requires heating, thus absorbing heat from the water. This core heat now becomes usable heat for the perimeter. If the amount of heat rejected equals the heat absorbed, it is not necessary for either the heater or cooler to operate. The same condition can occur when the system must supply cooling to some specific areas or functions in the structure while simultaneously supplying heating to others. This allows a transfer of energy to take place within the structure without requiring the operation of heater or cooler equipment.

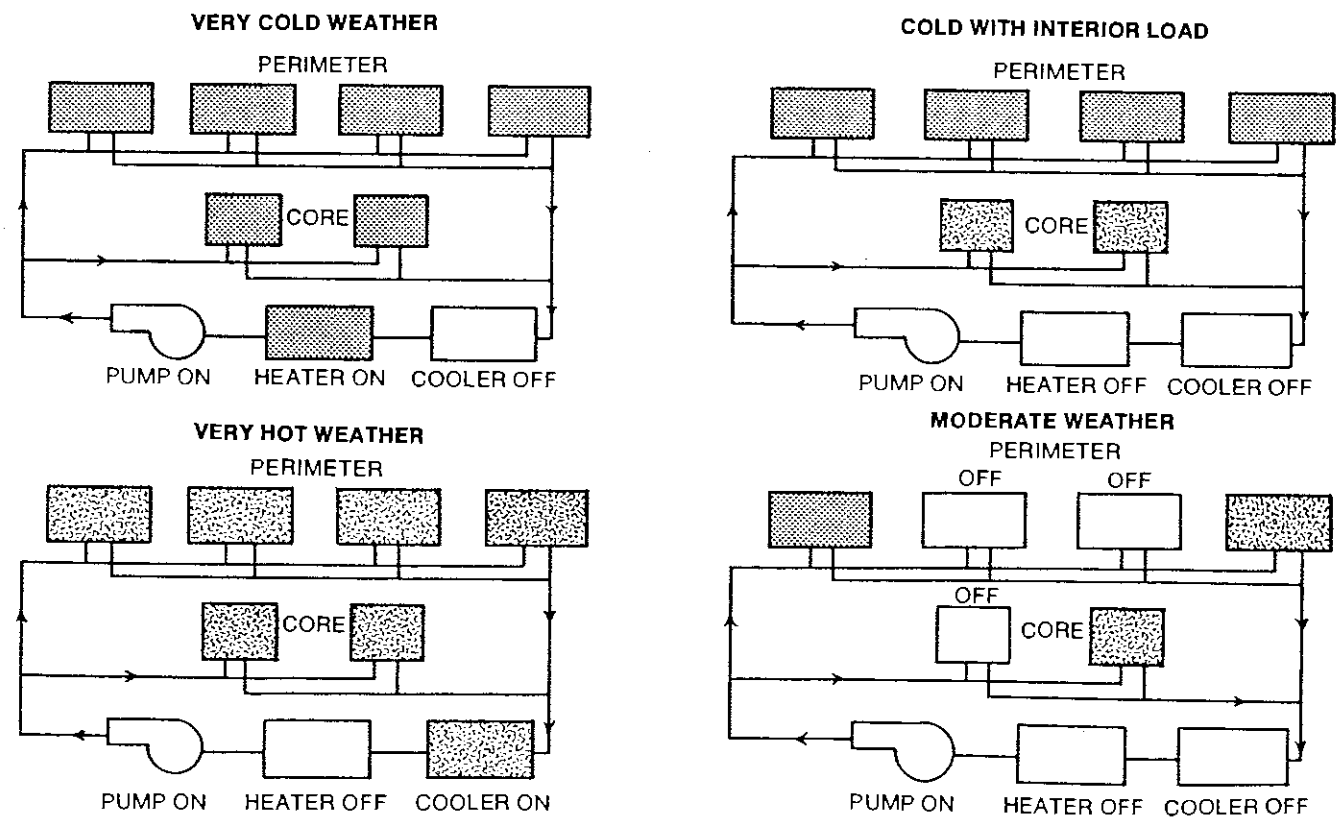
The water circulating system has a normal operating temperature range of 60° F to 95° F, and the operating controls are programmed to maintain the temperature within these limits. On a water temperature drop into the low 60's, heat is added in steps in order to maintain the water temperature at a minimum of 60°. This condition would occur under winter conditions as heat is absorbed from the water and used by the heat pumps to heat the air in the conditional spaces.

Conversely, on a water temperature rise into the area of 90°, unneeded heat is dissipated outdoors through the heat rejector or cooling tower in steps in order to maintain the water temperature at 95° or below. This condition would occur under summer conditions as heat is rejected to the water from the conditioned spaces.

During this entire cycle, any heat pump may use the loop water to provide either heating or cooling to the conditioned space. However, as a practical matter, it is unlikely that units will be called upon to provide heating when the water system temperature is above 80°. Thus, the operating ranges tend to be from 60° to 85° when perimeter heating (and core area cooling) are taking place; and from 75° to 95° when perimeter cooling (and core area cooling) are taking place. System design that could require significant operation in ranges other than these should be investigated for its effects on efficiency and reliability.

Figure 1

SYSTEM OPERATION



II. Advantages of the System

The concept of Heat, Recovery provides the most unique and reliable decentralized approach to comfort conditioning of multi-room buildings. The advantages of the system include:

Energy Savings

Water-source heat pumps are inherently more efficient than non-water cooled units. This translates into lower consumption of energy and lower operating costs. Energy usage can be flexible to take advantage of the most economical costs, since the heater can utilize electricity, fossil fuels, or solar energy as the heat source.

Advantages to the Owner

Immediate savings are realized by the lack of complexity and quicker installation time, due to the simplicity of design and installation flexibility. Moreover, the owner benefits from other advantages, such as less complex start-up problems and minimium risk of downtime due to the decentralized approach.

Advantages to the Tenant

Each occupant can be provided with individual control of heating and cooling throughout the year, regardless of outside conditions. A simple thermostat can be set at the desired comfort level. Usable space is increased, due to the compact design of the system. This allows more flexibility for office or room partitioning layouts and storage space.

The HEAT RECOVERY SYSTEM specifically has these advantages:

Lower First Cost

The System incorporates factory-built modules as basic components, and thus requires less costly field labor than built-up systems. Self-contained temperature controls minimize expensive field temperature control contracts.

Lower Maintance Costs

Because of the use of standard components, all items are easily repaired or replaced if necessary. Due to simplicity of design, the costly services of highly skilled operating engineers are not required.

Lower Operating Costs

The System uses building energy and transfers it to wherever it is needed. Due to the unique design of the System, auxiliary components operate only as needed. Energy is used only where it is required. Because of the multiple zones available, the operating diversity is extremely good.

Energy Availability

The basic energy requirement is electric. However, the heater can be one which utilizes electric, fossil-fueled, or solar heat sources. This offers maximum flexibility in use of the most economical energy source.

Noise Control

Noise pollution is as much of a problem as air pollution. But with a Heat Recovery System, there are no large boilers which pulsate; no reciprocating or high-speed centrifugal chillers; no high-speed, high-static centrifugal fans — all of which cause noise. The modules are acoustically lined and the equipment is factory-tested for minimum noise, acceptable in a variety of applications.

Installation Flexibility

At the time of installation, changes can be made easily with the individual components. Many different piping and electrical arrangements are possible. Most building peculiarities can be handled without difficulty.

Quicker to Install

Since the units are factory-packaged components, the only required field work may consist of some low pressure ducting, electrical hook-ups, and inter-connecting uninsulated piping. The piping can be steel, copper or plastic. Pumps, cooler and heater, and a minimum of temperature controls are required.

Less Space Requirements

Due to elimination of large duct systems, boilers, chillers, heat exchangers, multiple pumping, and accessory equipment, more space becomes available for actual tenant use. For the owner, this results in a greater return on investment. Costly equipment penthouses are usually eliminated.

Simple Temperature Control

Controls are electric and self-contained, or can be wall-thermostat mounted. The only other controls necessary are those needed to monitor water temperature. Because of the elimination of expensive controls and large electronic panels, the actual maintenance costs go down and the tenant better understands his temperature control system.

Flexibility of Installation

Individual modules of the system can be easily moved to allow for tenant changes with minimum disturbance. Rezoning is easy to accomplish, including changes in initial installation of interior and perimeter areas, or creation of special rooms.

Minimum Risk of Loss Due to Downtime

Since the Heat Recovery System does not depend upon large central systems, the heating or cooling of the entire building cannot be lost due to a large equipment failure. If individual units should fail, they can be easily replaced within 30 minutes. This insures greater tenant satisfaction and reduces the risk of lost rents.

Fewer Start-Up Problems

Any system requires a start-up procedure. Most systems take months to start up effectively due to complex air, hydronic, and control balancing. But the Heat Recovery System can be started and balanced within days.

Simple to Design

With the use of pre-engineered catalog items, components or modules can easily be selected to fit varying loads. Due to a minimum of controls, low pressure ducting, and simple piping, the design time for a Heat Recovery System is usually half that required for conventional systems. This factor means faster design and a substantial saving in design time and cost.

Year Round Individual Control

Each unit has its individual temperature control. This allows each occupant to control his comfort conditions of heating and cooling year round. Zones can be as small as 100 square feet or as large as many thousands of square feet.

III. Typical Applications

The system can be applied to any structure. The system offers top operating economies in structures which have excess heat, or large core areas from which heat can be recovered and transferred.

Many features of this system, other than heat recovery, also suit the particular requirements of such structures. Major advantages include individualized temperature control all year round, savings in space, nominal first costs, flexibility of installation, low maintenance and operating costs, and speedy design and installation resulting in an early return on investment.

Since the system is basically all-electric, air pollution can be reduced to zero, and this is an important factor in many areas. Where a fossil-fueled heater is required as the heat source, usage is very low, usually in the range of 50% of the capacity of the full heating requirement.

The variety of sizes and configurations of the Climate Master line of water-to-air heat pumps allows them to be applied in many ways such as in closets, mechanical rooms, ceilings, rooftops, along perimeters, free-standing, semi-recessed, fully recessed, in basements, garages, penthouses, etc. These systems, comprising various sizes and types of units, have been successfully applied in:

Apartments and Condominiums

These can be of multi-unit high-rise or garden type complexes. The advantages over conventional systems are:

- Individual metering
- Individual tenant control
- Lower first cost
- Lower maintenance costs
- Diversity of operation due to tenant occupancy
- Domestic water heating
- Recreational facilities such as swimming pool, ice skating, and clubhouse heat recovery

Hotels and Motels

The range of sizes of units furnished by Climate Master can provide total comfort for every size room from the small individual room to large public spaces. The innkeeper can take advantage of features like these:

- Ducted or free-standing models that are designed to be acoustically quiet for the comfort of guests.
- Individual units provide protection from complete shut-downs associated with a central system.
- Economy of first cost, operating and maintenance costs.
- The units can be installed a few at a time, in case of renovation.
- The units provide individual guest control.
- The units can also provide recreational, restaurant, laundry, and domestic water heat recovery.
- Maximum operating economy with front desk control and low limit.

Schools and Dormitories

The system, besides being widely specified for new school construction, is easily adaptable for renovation and modernization.

- Concealed system eliminates tampering and vandalism.
- Each classroom can have individual control.
- Units can be easily adapted for fresh air control.
- Economy of operation is achieved with night set-back controls and daytime programmed operation.
- Simplified design and operation can easily be maintained by custodial people.

Office and Commercial Buildings

This system is extremely adaptable for applications of this kind. Most office and commercial buildings contain constant internal heat sources which can be easily recovered. In order to attract tenants, owners and developers can offer individual year-round temperature control, with a minimal first cost and low maintenance and operating costs. The Heat Recovery System also offers other tenant and owner advantages:

- Minimum downtime in case of malfunction
- Night setback controls for economy of operation
- Programmed daytime controls for energy savings
- Off-hour use controls for economy and convenience
- Flexibility in partitioning
- Space savings for more use of office equipment and people
- Quiet, comfortable operation
- Flexibility in design, allowing various spaces to be completed only as needed
- Separate metering
- Easy design
- Quick installation and early return on investment
- Existing two-pipe fan coil systems can easily be converted to a Heat Recovery System to provide the flexibility of simultaneous heating of some spaces and cooling of others which was impossible with the 2-pipe system

Individual Recreational Facilities

Such facilities normally have a wide variety of uses, which often involve cooling and heating at the same time, as well as varying requirements for comfort control. The Heat Recovery System allows for these variances and at the same time can recover heat and transfer it to other areas. Such facilities are:

- Swimming pools
- Tennis courts
- Ice skating rinks
- Domestic hot water heating
- Gym and recreational facilities

Shopping Centers and Malls

Central shopping centers and malls are much like office buildings in that they contain large internal areas where heat can be recovered. Also, such areas often have multi-tenant usage, each requiring its own control. Such tenants can be separately metered for cost control. The Heat Recovery System allows flexibility in design for comfort control, ventilation and economy of operation plus lower first cost. Large mechanical rooms and big ducts are normally eliminated, thus providing more rentable space.

Supermarkets

Today's supermarkets use many varieties of refrigeration equipment for the storage, preservation, and display of frozen and refrigerated foods. These include ice-machine equipment, walk-in freezers, and refrigerated display cases. All of this equipment gives off heat. With the Heat Recovery System, this heat can be captured and used for general store heating or transferred to adjacent stores on the same system.

Computer Centers

Most computers require air or water for cooling. Such cooling devices are usually water-cooled air conditioners designed for the computer room. This heat can be absorbed with a Heat Recovery System and reused in parts of the building or other buildings, where heat may be needed. In some cases, enough heat can be recovered from computers to heat an entire complex without the need for any additional heat sources.

Residences

The heat Recovery System is very applicable to residences and offers the following advantages:

- Year-round control of heating and cooling
- Efficiency of operation
- Use for domestic hot water heating
- Use in conjunction with swimming pools for heating water
- Can be integrated with a solar system for all-house heating-cooling with combination solar panels and water-air transfer.

Restaurants and Fast Food Chains

Since it is compact, easy to design and install, and highly efficient, the Heat Recovery System is well suited for use in food chains. Here the system takes advantage of internal heat transfer. This energy can be transferred for preheating incoming air required to replace air exhausted from kitchen hoods.

Medical Buildings, Nursing Homes and Hospitals

The concept of de-centralized zone units provides the diversity required to meet the different comfort levels of different patients. The system works extremely well in hospitals, nursing homes and other medical buildings because of:

- Isolation in air supply. The unitary system prevents room-to-room contamination.

- Dependability and provision for almost instant replacement in case of malfunction. The reliability of the equipment and its simplicity of operation automatically eliminate trouble of various kinds.

Marine Applications

The System is well suited to all types of vessels which require either heating or cooling, whether the boats are small pleasure craft, or large merchant marine vessels. By using cupro-nickel condensers, salt water or fresh water can be circulated as the cooling or heating medium.

Spaces within the vessels give off heat. This heat is recovered and transferred to other areas. The individual units provide constant de-centralized control with varying outside temperatures and somewhat varying sea water temperatures.

Industrial Applications

Most industrial plants have exhaust and make-up requirements. Associated with such facilities are general office spaces. A properly designed water source heat recovery system can take advantage of operational processes to recover heat and use it to maximum advantages with other simultaneous processes within the structure.

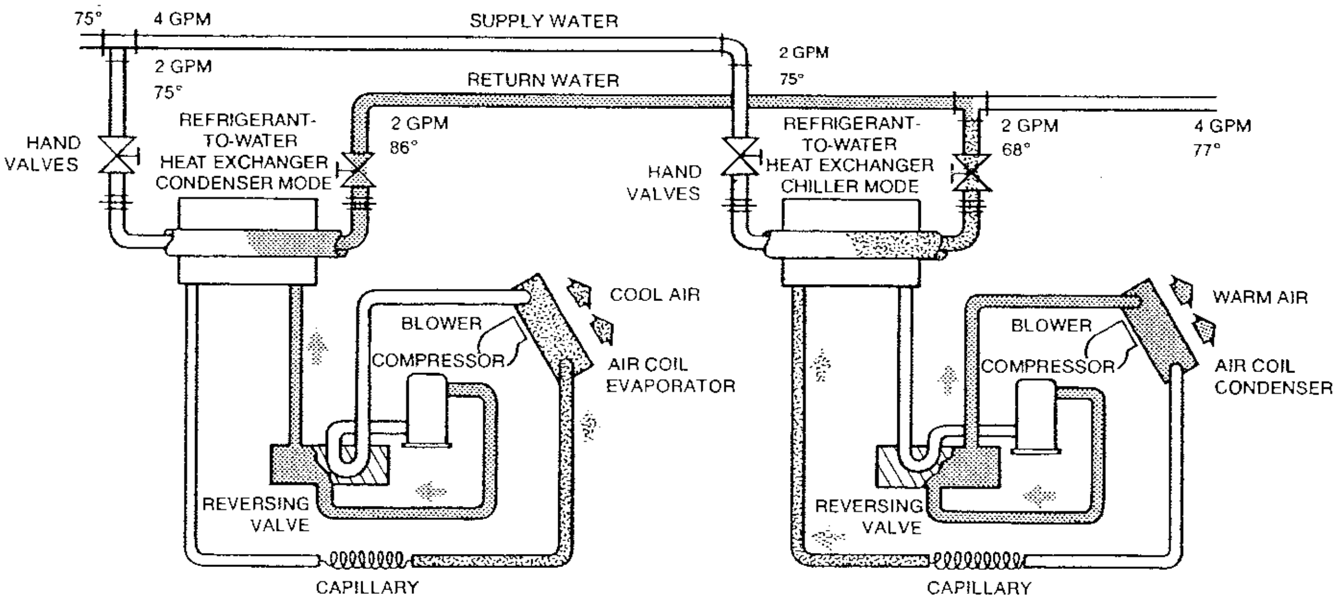
IV. How the Unit Works

Basic principle of operation of the Climate Master water-to-air heat pump: heat is rejected to the water from the air being conditioned (cooled) on the cooling cycle, and heat is absorbed from the water by the air being conditioned (heated) on the heating cycle. De-humidification is also achieved on the cooling cycle by removal of moisture from the air in the form of condensate. The medium of heat transfer is the refrigerant. Basic components used in the refrigerant system are the hermetic compressor, co-axial refrigerant-to-water exchanger, a finned coil refrigerant-to-air heat exchanger, a blower motor to circulate the air, and a capillary or refrigerant metering device. The system reverses from the cooling to heating cycles by means of a reversing valve. A thermostat signals the unit to operate on the cooling or heating cycle. When the preset comfort level is achieved, the unit will turn off automatically.

In **Figure 2**, a schematic of two units in operation is shown, one on the cooling mode and the other on the heating mode.

Figure 2

**WATER-SOURCE HEAT PUMP
HEAT RECOVERY CYCLE**



**COOLING CYCLE
UNIT A**

**HEATING CYCLE
UNIT B**

UNIT A

In the cooling mode, heat is absorbed through the air coil from the space being cooled and transferred via refrigeration to the water coil where it is rejected to the circulating water through the water coil. This causes the water temperature to rise. In this example with 2 GPM of water entering at 75° F, the temperature rises to 86° F.

UNIT B

In the heating mode, heat is absorbed from the circulating water through the water coil and transferred to the air coil by refrigeration, where it is rejected to the area being heated. This causes the circulating water to drop in temperature. In this same example, the 2 GPM of water entering at 75° F is lowered to 68° F, but Unit B on the heating mode lowers the water to 68° F. Since both units are on the same loop, the resultant **mix** temperature is 77° F.

If a third unit were on the same loop and it too were on the heating cycle, the resultant mix temperature would be 74° F.

This one unit on the cooling cycle adds enough heat to the circulating water to support two similar size units on heating without a significant change in water temperature of the loop.

This phenomenon illustrates the great practicality of the heat recovery system. Namely, that while certain units are on the cooling cycle and adding heat to the water, other units are on the heating cycle and are absorbing this heat. Thus a transfer or recapture of heat or energy is accomplished without using either the system heater or cooler.

V. Application of the Units

The Climate Master Water-to-Air Heat Pump product line includes the most versatile and comprehensive model line-up in the industry. The full range of sizes, the availability of free-standing and ducted units, and the configuration flexibility result in relatively easy application of the units. The correct location and method of installation of the individual heat recovery units should be considered in the process of designing the system. One of the prime considerations should be access for inspection and service of components within the unit.

Refer to the Climate Master Engineering Product Catalog to determine information on the following:

- Performance curves and ratings
- Dimensions
- Specifications of components
- Electrical wiring diagrams
- Accessories

This section will cover general application techniques, piping suggestions, mounting and installation suggestions, field wiring suggestions and control arrangements.

The products which comprise the Climate Master Series are as follows and as shown in **Figure 3:**

A. Console

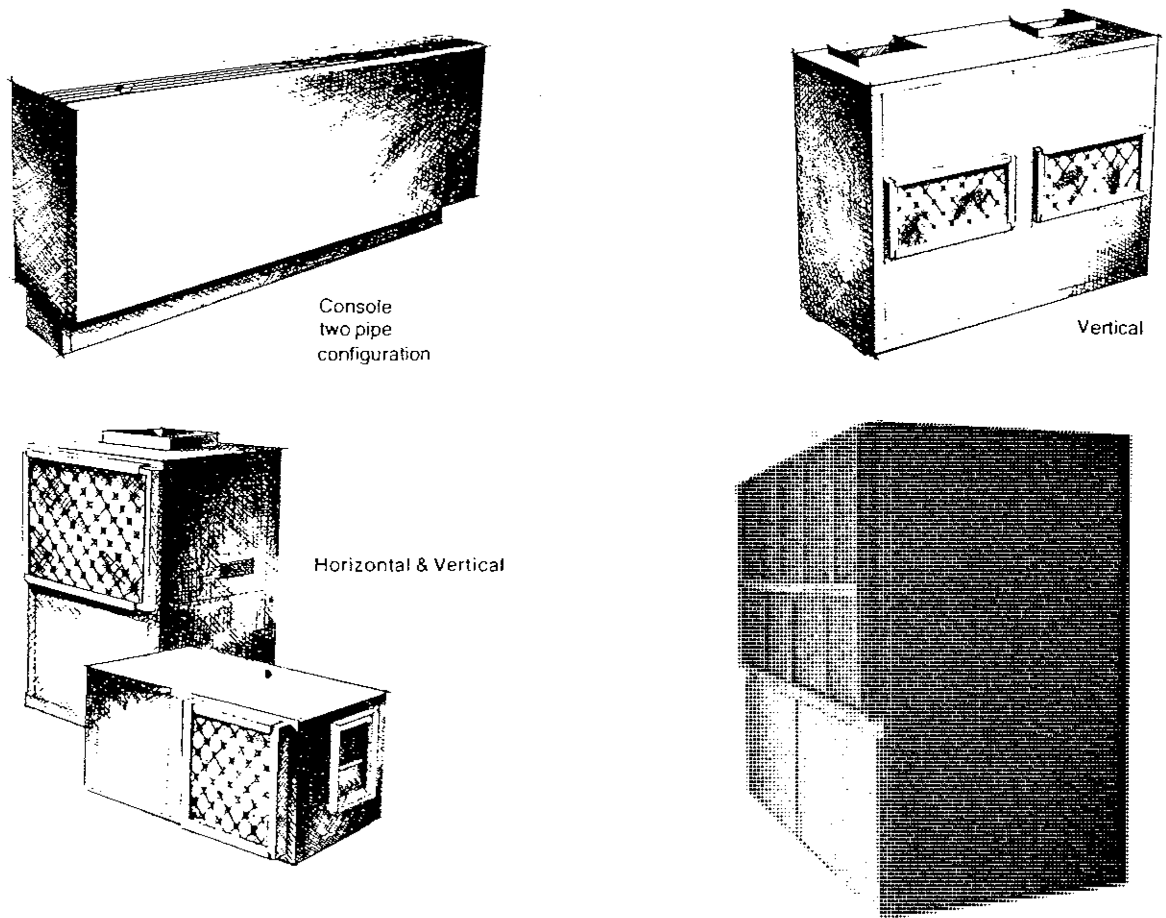
B. Vertical

C. Horizontal

D. Large Tonnage Vertical

E. VAV Varimaster

Figure 3



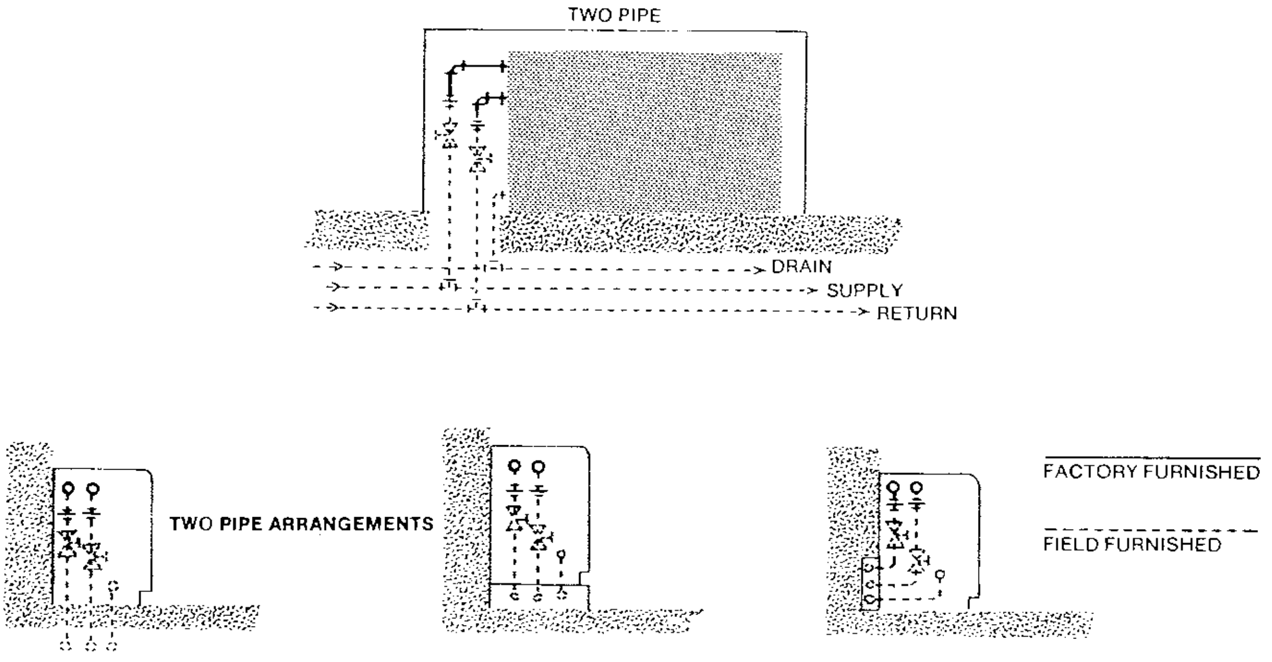
A. Console Units

The 801 Series of models is a console nonducted unit. These console model units are ideally suited for perimeter areas, or for conditioning a single non-partioned zone such as a motel or hospital room. They are also suitable for single or multiple fixed interior spaces. Furnished with a decorative cabinet, they are normally located within the room or space to be conditioned — usually on the floor at the outside wall, but they may be mounted at any interior wall. The unit can also be furnished without the cabinet for use in a custom enclosure. All units can be recessed 5" to 6" if desired.

This is the only series of models that features the single and double pipe concept available in both left and right hand units. **Figure 5** shows various methods of piping both the one-pipe and two-pipe models in order to take best advantage of the architectural features of the building design for maximum mechanical flexibility. Refer to the Product Catalog for detailed dimensions of the complete unit and the unit-less-cabinet.

Figure 5

CONSOLE PIPING ARRANGEMENT



B. Vertical Series

These are commonly used in apartments, condominiums, and core areas of office buildings. The configuration helps save space. The unit is usually set above the hot water heater in apartment applications. The air is distributed through ductwork to the various rooms. The return air options permit ease of application in unusual closet configurations. Typically, a platform is built above the water heater and the unit is placed on rubber-in-shear isolators on the platform.

These units can be installed where the room acts as a return air plenum. When doing so, always allow adequate distance between the filter and the wall or door for proper air return. The units can also be equipped with return air ducts. The units are lined on the interior with thermal insulation of extra-heavy density to provide acoustical absorption.

However, to minimize transmission of sound, we recommend the following general procedure for both the Series 813 and V units.

1. The units should be isolated from the ultimate supportive structure with such devices as isomode vibration pads, or rubber and cork.

2. A duct collar is provided as standard equipment for attaching supply air ducts. The ducts should be attached to the unit with a flexible connector to prevent sound transmission and vibration. If a return air duct is used, it can be provided with an optional duct collar for attaching the return duct. This duct should also be connected with a flexible connector to prevent sound transmission and vibration.

3. To minimize sound in applications where the unit is located in a room being used as a return air plenum, locate the return air grille away from the air conditioner rather than right next to it. If the return air grille must be next to the unit, and if the sound level is higher than desired, a simple acoustical baffle may be installed at the return air grille or at the return air coil.

4. The air velocities in the duct work and water velocities in the main piping should be maintained within levels recommended in the ASHRAE handbooks to prevent excessive noise. The procedure for sizing the piping and duct system is outlined in the following chapters.

5. All units should be connected with appropriate hand valves and unions, or flexible hose, so that the basic unit can be isolated from the main piping system.

6. The unit contains a built-in, self-contained electrical control box for connections of power wiring and low voltage thermostat wiring through convenient knockouts. It is recommended that in the close vicinity of the unit (or per local codes) a disconnect switch be provided. This will provide ease of serviceability and inspection.

7. Proper drain connections should be made for condensate removal with an appropriate trap.

Auxiliary equipment should be installed in accordance with the manufacturer's recommendations.

Space requirements for proper equipment installation, air flow and serviceability are extremely important for unit performance and life expectancy.

See **Figures 6, 7,** and **8** for suggested installation procedures.

Figure 6

TYPICAL VERTICAL UNIT INSTALLATION SERIES 813

Left Hand Return shown. Refer to Product Engineering Catalog for other arrangements and dimensions.

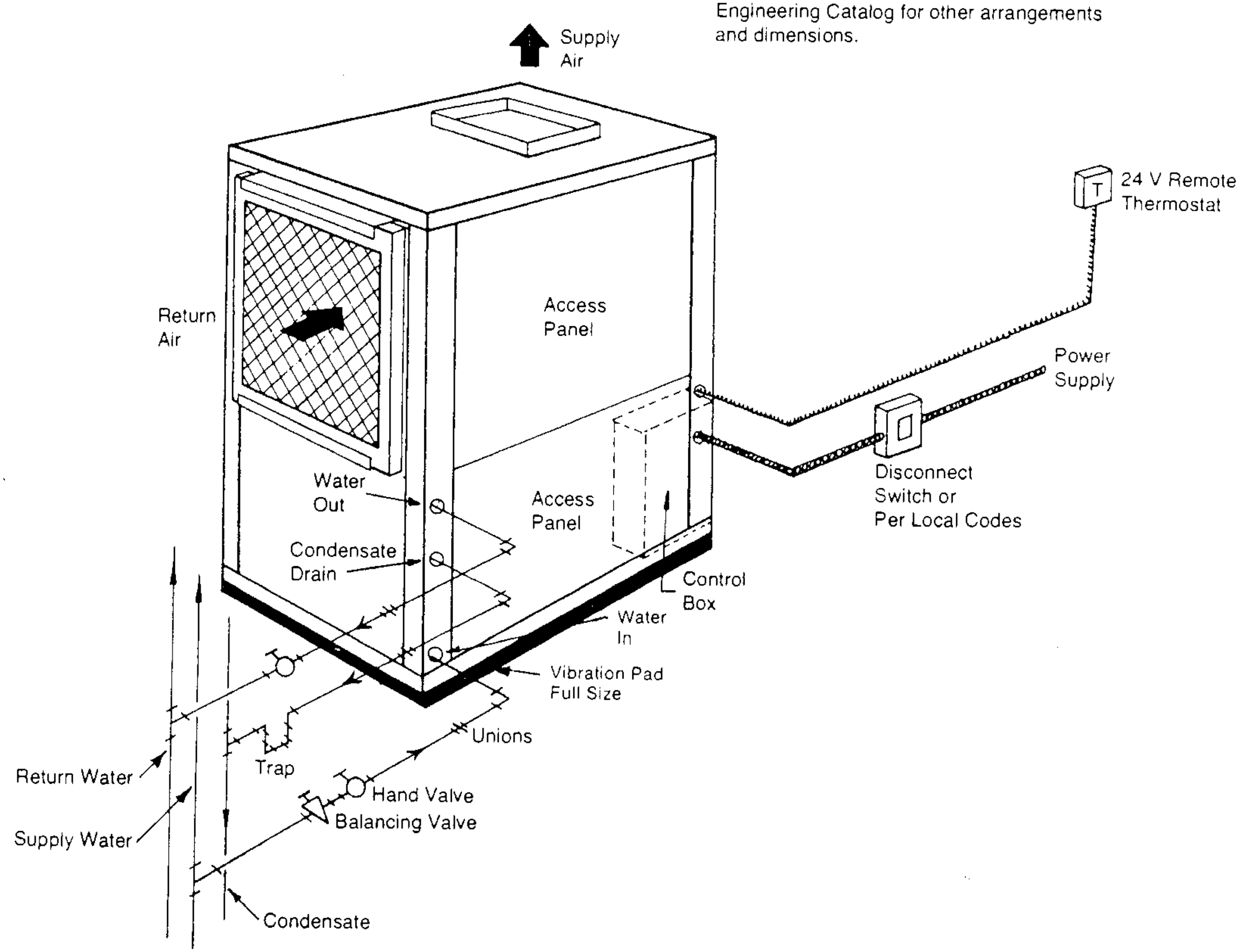
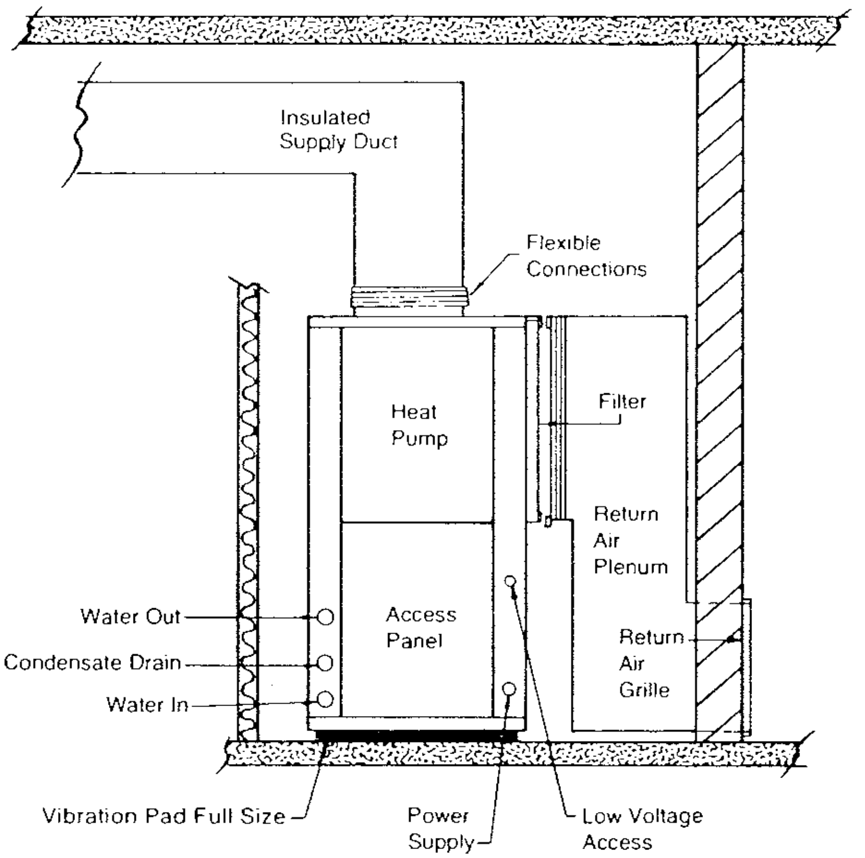
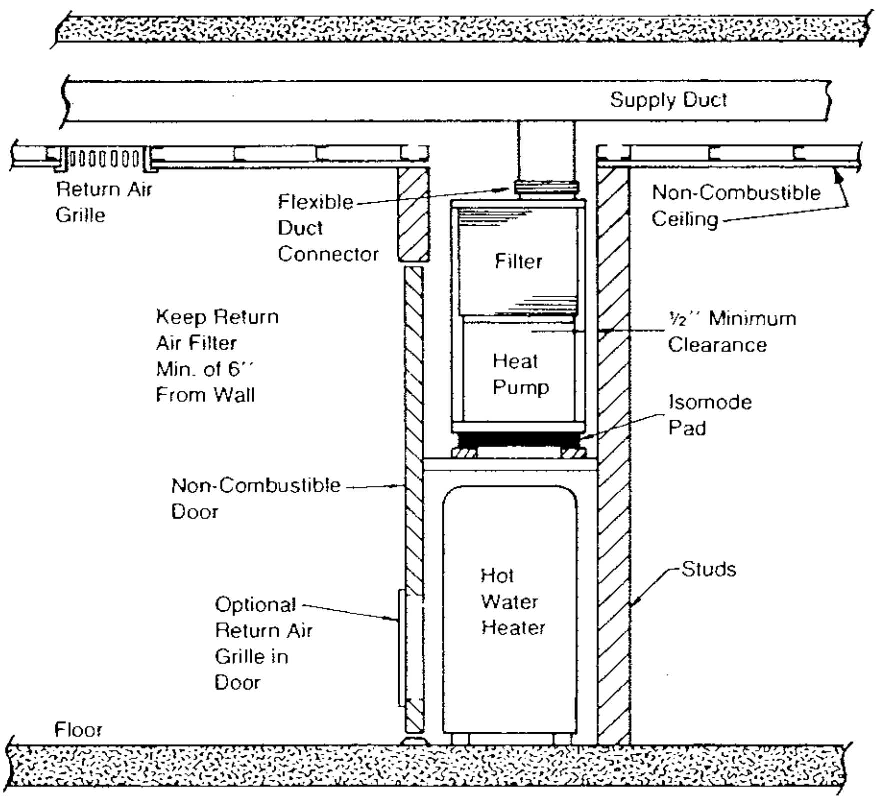


Figure 7



Arrangement of Unit in Closet or Mechanical Room
Ducted Return

Figure 8



Arrangement of Unit over Water Heater in Closet
Free Return

C. Horizontal Series

The horizontal configuration of the ducted units is ideal for concealed ceiling-mounted applications. The units are available with optional isolation-type hanger brackets. This model also is available in different return air configurations to enable the optimum in space saving application. The unit has several removable panels providing ease of serviceability.

In general, follow the same procedures for sound treatment as outlined under Section B for the Vertical Series.

The ceiling mounted unit is shown in **Figure 9**. In this case, the ceiling is used as a return air plenum with a return air grille mounted in the ceiling. Use of a discharge duct with at least one change of direction is important to realizing lowest sound level. Free air discharge is not recommended when low sound level is important.

Use of acoustical tile on the ceiling is also effective for sound attenuation. Units should be hung from the ceiling either with the factory-furnished hanger kits or by isolated cradle furnished by others.

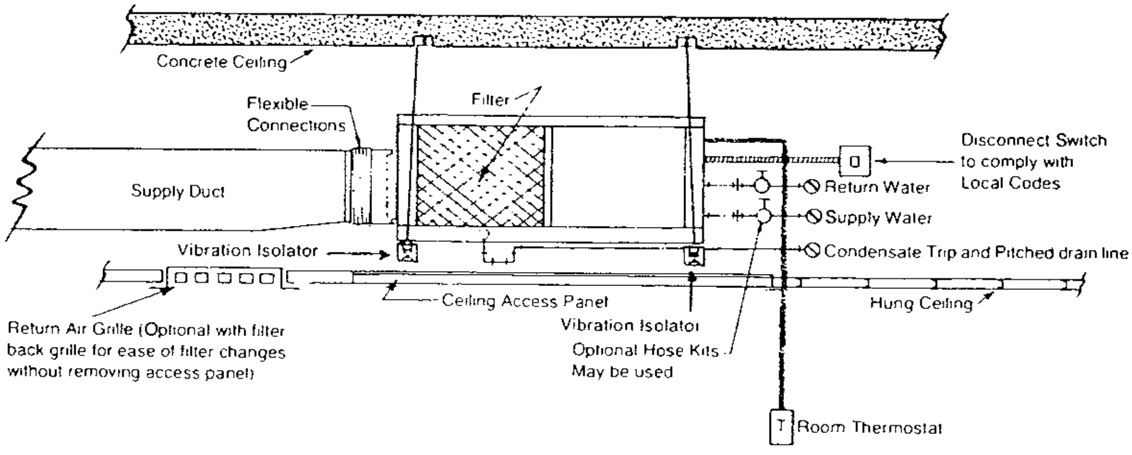
The horizontal units have a standard discharge collar for ducting and should be connected with flexible connectors. The return air can be supplied with an optional collar for return air ducting connected with a flexible connector. For free air return, try to locate the return air grille away from the unit.

Always provide adequate ceiling removal panels for easy access to the unit for service.

For additional sound treatment, a return air sound plenum can be attached to the return air inlet or outlet. Recommendations for piping, electrical equipment, condensate drains, ducting, auxiliary equipment and space requirements as discussed for the Vertical 813 also apply for the Horizontal 814.

Figure 9

TYPICAL CEILING UNIT INSTALLATION
SERIES 814



NOTE Diagram illustrates using Unit with ceiling as Return Plenum Return Duct can be used with Return Collar as Filter

NOTE Refer to Product Engineering Catalog for exact dimensions of electrical and piping connections & locations

Vibration Isolators See Product Engineering Catalog for details

D. Vertical Series V

This series of equipment ranges in size from 80,000 to 300,000 BTU cooling. The units are completely factory-packaged in a unitized, heavy-duty steel cabinet. The units are designed for vertical free-standing application in mechanical rooms or closets with ducted discharge and either ducted or non-ducted return. They are connected to the closed water loop and can provide either heating or cooling all year round, in conjunction with the heat recovery system.

• All controls are centralized in a control box requiring single-point connection of power wiring and low-voltage thermostat control wiring. A field-supplied disconnect switch located within sight of the unit, or located in accordance with local codes is recommended.

• All condenser and condensate drain piping is interconnected, requiring quick field connections to piping through female fittings.

• The units are designed to require minimum floor space and the widths of all units are such that the units will pass through a 30" door.

• Large removable panels are provided for ease of servicebility of the fan, compressor, coil and control sections.

• Units are offered in both single and dual conpressor arrangements for maximum flexibility, efficiency and control.

• The fans are large, slow-speed, centrifugal models with high static load capability in order to meet the demands for extended ducting, special intakes and filtration methods.

• All units are treated acoustically for minimum noise. Compressors are mounted on rubber isolators. It is recommended that rubber and cork isomode pads be used at the bottom of the units to minimize structural borne sound transmission.

• The units are designed for maximum flexibility in discharge and return air configurations. There are 6 variations per unit, (except for V-300) allowing freedom of design and field installation techniques.

Refer to the Product Engineering Catalog for detailed information on capacities, ratings, dimensions, configurations and electrical data.

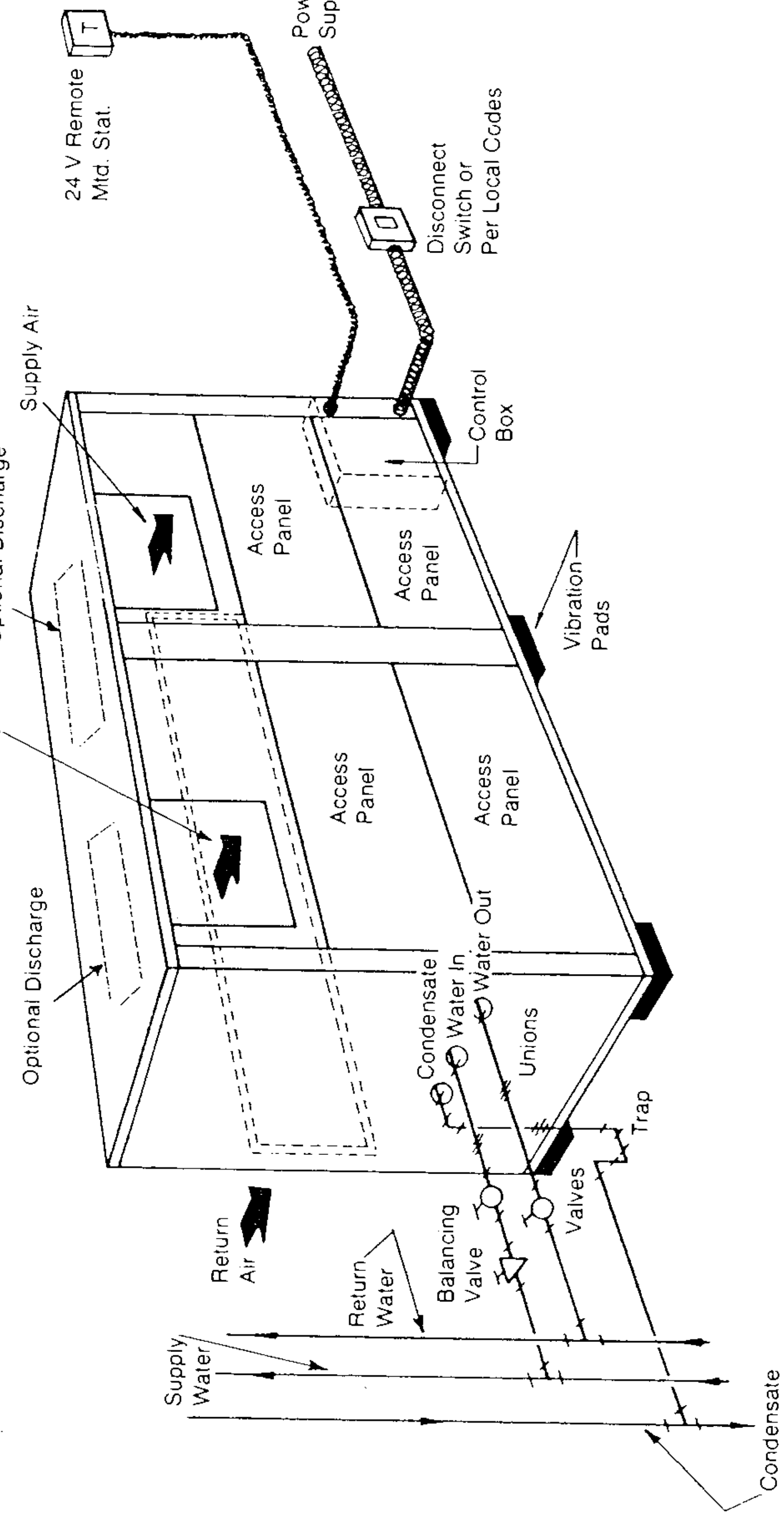
Refer to **Figure 10** for recommended installation.

Figure 10

VERTICAL UNIT PIPING ARANGEMENT SERIES V

Rear Return Front Blow shown

Refer to Product Engineering Catalog for other arrangements & Dimensions



E. Electrical

The Climate Master units are available in multiple options of electrical power supplies. This flexibility enables the engineer to select the most convenient or economical power supply for the equipment.

Series 813-814 and V

The units are available with manual or automatic changeover thermostats. "Manual changeover" enables the occupant to manually change the unit from the cooling mode to the heating mode. The "Automatic changeover" option allows the setting of the thermostat at a given temperature, which automatically signals the unit to provide cooling or heating, whichever is required to maintain the preset temperature.

The units operate with controls at 24 volts. The pre-wired, factory-furnished unit requires the installer to simply connect the power wiring and route the low voltage wire from the unit to the thermostat. Single connection power supply is required for all models including dual compressor circuits.

The units are furnished with safety devices that sense abnormal operating conditions and automatically shut the units off. An exclusive feature available on Models 813-814 is the ability to reset the machine at the thermostat or at the power supply source. Models V can be reset only at the thermostat. This feature permits reset of nuisance tripouts without having to push reset buttons within the unit or having to remove panels. At the same time, the need for repeated resets would be a clear signal of the need for attention to the unit, whereas repeated automatic resets might go unnoticed until the problem reached a more advanced stage.

Refer to Product Engineering Catalog for electrical ratings. This data enables you to size the electrical load to the building for the air conditioning units, and the fuse and feeder size to each of the units.

For specific unit wiring diagrams, refer to the Product Engineering Catalog.

The dual models are equipped with two stage thermostats that provide capacity control. There is also a time delay between the starting of the two compressors, to prevent excessive locked-rotor starting current. Disconnect switches should always be installed adjacent to the unit for service procedures or as various local codes require.

Series 801 Console

Available UL-listed controls consist of:

1. Manual changeover with unit-mounted adjustable thermostat is the standard control arrangement.

2. Automatic changeover with unit-mounted adjustable thermostat.

3. Manual changeover with low voltage 24V wall-mounted remote thermostat.

4. Automatic changeover with low voltage 24V wall-mounted remote thermostat.

5. Master-slave control with 24V manual or automatic changeover wall-mounted thermostat.

6. Motorized or manual outside air damper.

Control packages which are available with UL listing consist of:

1. Security Guard provides for a central control to put all units into a night set-back mode for overnight, holiday, or weekend operation; at the same time, it permits local override for the benefit of offices in use after hours. It is either manual or automatic changeover with random start program relay circuit, low limit override thermostat, and 2 hour reset time for off-hour use.

2. Circuit breaker assembly for 208/230.

3. Circuit breaker assembly for 265.

4. Disconnect switch box assembly for 208/230/265.

All console units contain built-in safety devices for high pressure and low water temperature with manual reset Hermetically sealed compressors contain internal overload and fan motors contain built-in overload protection.

VI. Zone Design

The Climate Master Series of Water-to-Air Heat Pump units uses the most efficient methods to assure controlled comfort in all seasons. In addition to providing air circulation and temperature control, the system also dehumidifies with its cooling mode, and filters the air. The Heat Recovery System features a decentralized concept in a large building and divides the space into definite zones.

This section provides base criteria for the design and selection of a single heat pump applied in a structure with multiple units. The complete system will include additional units, piping, coolers, heaters, pumps and controls. For a system analysis, we have chosen an office building which involves all the varieties of heat pumps. The analysis will include a step-by-step selection of the auxiliary equipment.

Refer to section VII for this analysis.

A. Selection of the correct configuration of the unit:

Figure 12 shows a typical single-unit zone configuration for an apartment or condominium or other residence. Selection and location of the equipment are extremely important in order to minimize ducting, provide optimum location of return air and location of water supply, and assure the most favorable performance in the areas of air return and condensate removal as well as electrical serviceability. In this example, a utility closet was provided. It acted as a return air plenum with a service door to the corridor. The unit configuration is vertical, is placed above the water heater, and contains an electrical panel for the air conditioning, water heater and apartment services.

B. Selection of the size or capacity of the unit:

The thermostat controls the temperature of the environment. However, if the unit is undersized, it will continue to run and possibly be incapable of meeting the demands of the thermostat. If the unit is oversized, short-cycle performance may result, that is, the unit may run for a short period, satisfying the temperature requirements set by the thermostat, but may not be able to dehumidify to a satisfactory comfort level. The selection of a unit size is estimated or calculated according to a set of guidelines based on the indoor and outdoor temperatures of the design. A heat load for cooling and heat loss for heating for the space or zone should be planned on the basis of factors such as:

1. Orientation and geographical location of the building.

2. Wall areas, construction, insulation and exposure.

3. Window glass area for each wall and exposure.

4. Ceiling or roof areas, construction and insulation type.

5. Floor areas, construction and insulation.

6. Identification of heat producing appliances, equipment and lights.

7. Influence of ventilation and exhaust requirements, introduction of humidity and people-oriented loads.

The Air Conditioning and Refrigeration Institute has established a standard for designing a year-round residential system. The purpose of Standard 230 is to establish the following:

1. Define the air conditioning terms.

2. Design indoor and outdoor conditions.

3. Minimum ventilation requirements.

4. Factor and calculation procedures for heating and cooling loads.

5. Minimum requirements for air circulation and distribution.

Also refer to ASHRAE Standard 90-75 for additional design criteria.

Almost all applications other than typical residences would require a more detailed analysis. It would quantitatively identify the sources of heat gain or loss.

As an example, a typical single bedroom residence on the sixth floor of an eleven story apartment building is illustrated in **Figure 12**. The illustration, drawn to scale of ¼" to a foot, shows a Vertical Heat Pump located in a closet in the corridor area. The only exposures of the apartment to the outdoor ambient temperature are the bedroom and living/dining areas facing the balcony.

The design must take into account local codes and requirements. Reference material and the ARI Standard 230 are available from the:

AIR CONDITIONING & REFRIGERATION INSTITUTE
1501 WILSON BLVD., SUITE 600
ARLINGTON, VIRGINIA 22209

The sizing of the unit is based on using the ARI load calculation outlined in the ARI Standard. After evaluation of requirements and loads, a 813-019 is selected. Conditions of service, which determined the choice of the unit, are listed as follows:

COOLING

750 CFM at 80/64°F entering air
Total Capacity = 21,850 Btuh
Sensible Capacity = 15,902 Btuh @ 6.3 Gpm entering at 85°F, leaving at 93°F
Conditions: 80°F DB/67°F WB entering air

C. The Air Distribution System:

The air distribution system (ducts, supply and return grilles) for the unit should ensure the following:

1. A correct amount of air shall be distributed to maintain comfort levels in each zone.

2. The size of the duct should prevent extreme conditions of velocity. If the duct is too small, the velocity will be high, leading to high friction losses and potential noise problems. If the ductwork is oversized, excess air quantities will be delivered by the unit. Possible result: too much air across the coil may prevent dehumidification.

Proper duct sizing is also essential in order to maintain normal operating pressures within the refrigerant circuit. The units, the fan and blower have been designed to handle an external static pressure, and thus should not be applied without ductwork.

3. All supply air ducts must be adequately insulated and made properly moisture-proof by a vapor barrier. All joints must be sealed. The supply air connection to the heat pump unit should be accomplished by means of a flexible connector. In most small size heat pump applications, return air ducts can be completely eliminated; however, if return air ducts become necessary, they should be isolated from the unit by means of a flexible canvas connector or gasket that will prevent metal-to-metal contact between the heat pump unit and the return air duct.

In designing an actual duct system, two methods are widely used. One method is known as the velocity static regain method and the other as the equal friction method. The equal friction method lends itself more to the application of small capacity units and is the only one discussed here. In this method, the friction loss per unit length of ductwork is kept constant throughout the system; recommended friction is .08" of water per 100 feet of ductwork. To determine the total friction loss in the duct system, the constant friction loss per unit of length is multiplied by the equivalent total length of ductwork.

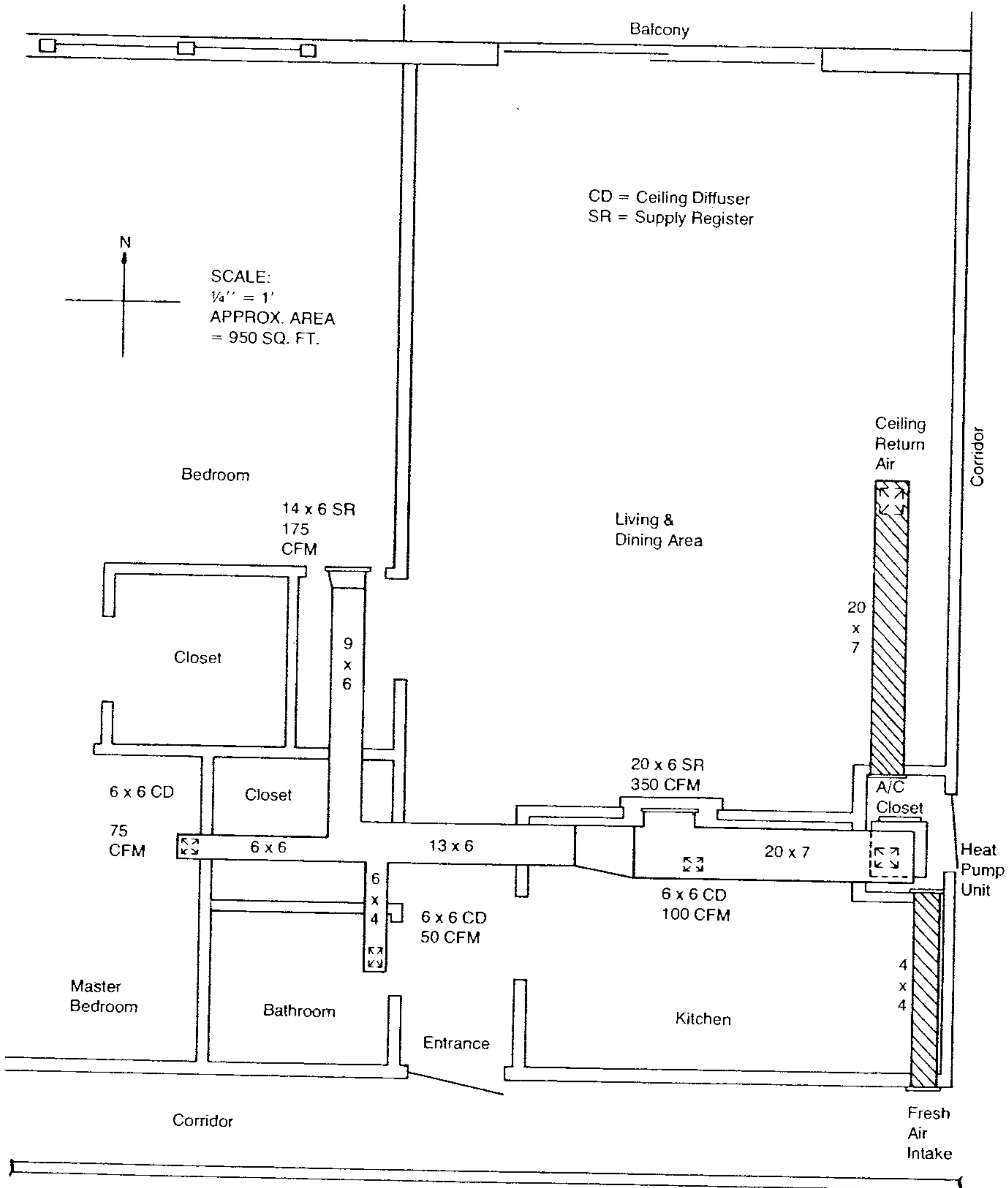
Return air ducts are designed in exactly the same way as supply ducts. In principle, it does not make any difference whether a blower pulls or pushes the air through the duct. In general, return air duct sizes are larger than supply air duct sizes.

It is recommended that all supply air and return air ducts should be kept to a minimum length. Turning vanes should be used in all duct turns. Balancing dampers may be installed within the ductwork. But under no condition should the heat pump be allowed to operate with less than the minimum air quantity recommended.

Proper care should be exercised in selecting supply registers and diffusers. Consult manufacturers' catalogs for details as to size and air distribution patterns. It is most important that each air outlet be selected for both the heating and cooling functions it will be required to perform.

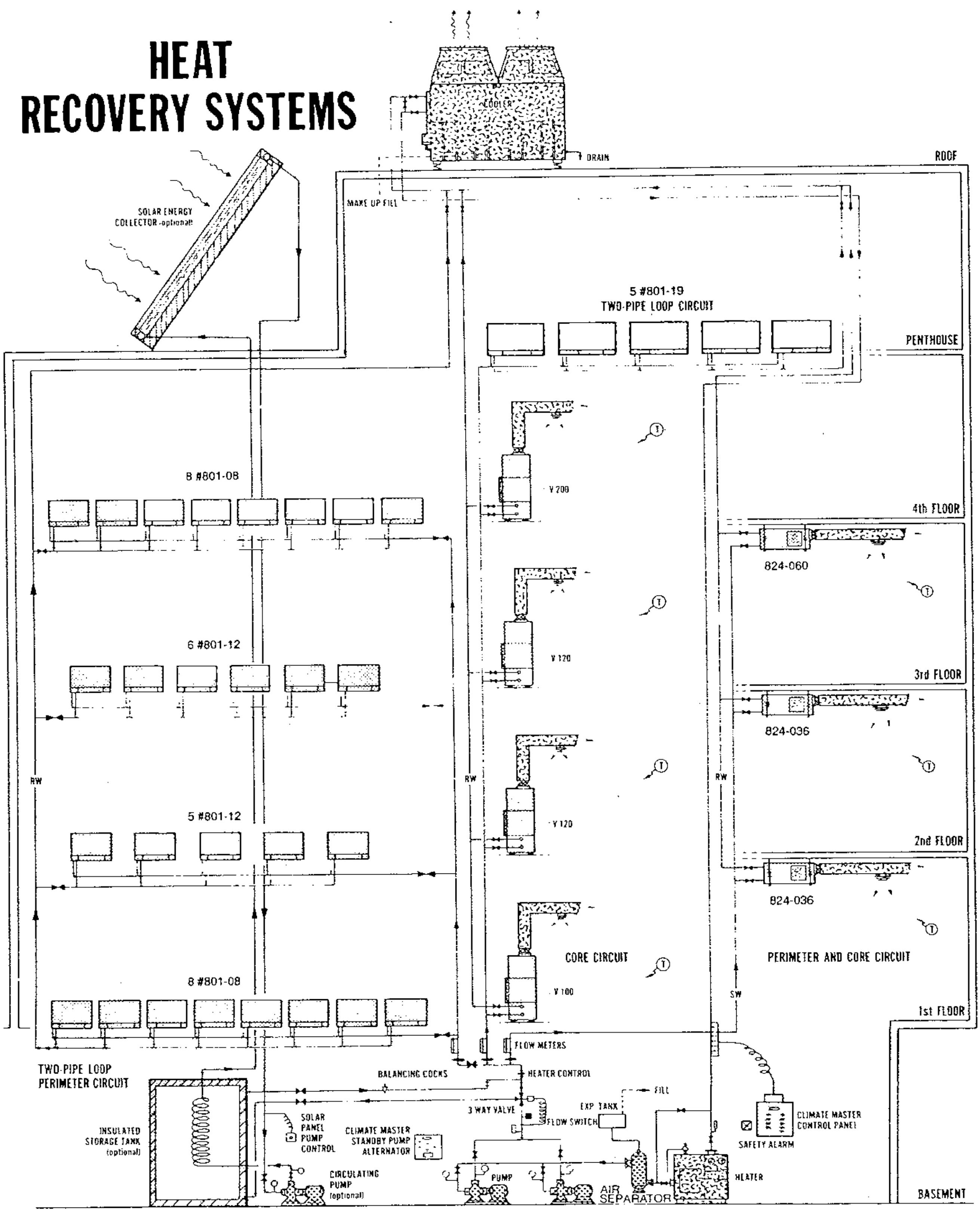
Return air grilles are usually of the non-adjustable type and should be installed so that they prevent sight into the ductwork.

Figure 12



TYPICAL ZONE AIR DISTRIBUTION LAYOUT

Figure 13


HEAT
RECOVERY SYSTEMS
COOLER
DRAIN
ROOF
MAKE UP FILL
SOLAR ENERGY
COLLECTOR optional
5 #801-19
TWO-PIPE LOOP CIRCUIT
PENTHOUSE
V 200
8 #801-08
4th FLOOR
824-060
6 #801-12
V 120
3rd FLOOR
824-036
RW
5 #801-12
V 120
2nd FLOOR
824-036
CORE CIRCUIT
PERIMETER AND CORE CIRCUIT
8 #801-08
V 100
SW
1st FLOOR
FLOW METERS
TWO-PIPE LOOP
PERIMETER CIRCUIT
BALANCING COCKS
HEATER CONTROL
FILL
3 WAY VALVE
EXP TANK
FLOW SWITCH
INSULATED
STORAGE TANK
(optional)
SOLAR
PANEL
PUMP
CONTROL
CLIMATE MASTER
STANDBY PUMP
ALTERNATOR
CLIMATE MASTER
CONTROL PANEL
SAFETY ALARM
CIRCULATING
PUMP
(optional)
PUMP
AIR
SEPARATOR
HEATER
BASEMENT

VII. System Design

This section will follow the procedure for selection of components to heat and air condition a small office building shown in **Figure 13** using the Heat Recovery System. Throughout this section, criteria will be stated and assumptions made which could vary from location to location depending on codes, atmospheric conditions and design. Therefore, each structure should be thoroughly analyzed. The criteria and assumptions made in this section are intended simply to illustrate the evaluation of some of the factors that may require consideration in making such an analysis.

The previous section on a residential zone containing data on ducting, grilles and diffusers can be used in this section for design of ducting for the core vertical units and separate zone ceiling horizontal units. This section will cover the following:

A. Building description and function

B. Heating and cooling loads

C. Unit selection and location

D. Ducting

E. Pipe sizing and arrangements

F. Heat rejector selection and options

G. Heater selection and options

H. Pump selection and options

I. Control selection and options

J. Ventilation

K. Solar Collection

A. BUILDING DESCRIPTION AND FUNCTION

This building is designed as a 4-story, 22,000 sq. ft. office building with a small board-room type penthouse. On each floor, there are perimeter offices on one side with glass windows and a 29" sill height of pre-cast panels. The glass is insulated with a solar bronze tint. The pre-cast panel is backed up with 3" insulation and dry wall finish. The back side of the building is all solid since it backs up to an adjacent building. The service facilities such as bathrooms, elevators, mechanical closets and electrical closets are at one end.

Although the building is somewhat small for a heat recovery application, it was selected because it meets, exceptionally well, the following criteria that had been established for it:

1. Offices facing the glass side are to be individual executive offices. Thus, each one requires its own temperature control.

2. Since the building has no exposed back side, the perimeter offices and core require cooling most of the time. This provides an excellent heat sink for transfer of energy to the glass side of the building.

3. Low first cost for an individually controlled space.

4. Low operating cost.

5. Low maintenance cost with simple procedures.

6. Simplicity of controls and flexibility of partitioning are desired along the perimeter wall since the partitions are not permanent and are subject to change.

In the selection of any system for a structure, the use of the building and the preferences of the tenants must be analyzed first. Normally, if individual perimeter temperature control is desired year round and there is a reasonable core area in the building, a water source heat pump system is an ideal selection compared to common forms of air conditioning and heating which require either costly complexity in a single system, or separation into two separate systems, in order to be able to simultaneously supply cooling for the core areas and heating for the perimeter areas — and still would not provide heat recovery.

The problem could be solved with a 3 or 4 pipe system, either fan coil, variable air volume or induction, but first costs are extremely high, and the system is vulnerable to a chiller breakdown. A 2-pipe fan coil system would be substantially less costly, but it cannot simultaneously supply economical cooling and heating, and it also presents the problem of chiller breakdown. An all-air system with an economizer cycle and zone reheat may offer lower first cost, but is expensive to operate when reheat is required. See ASHRAE standard 90-75 relative to reheat limitations, especially on double duct and multi-zone systems.

B. LOADS

It is necessary to calculate the heat losses and heat gains of the building before designing and applying the Heat Recovery System. Use the standard ASHRAE Handbooks and procedures to make these calculations after determining the basic building design and use factors such as:

1. Perimeter wall to consist of insulated tinted glass with pre-cast panels and insulation and dry wall finish.

2. Back and end walls to be brick and concrete block, with vapor barrier furred out 2" with air space and dry wall finish.

3. Roof to be built up with tar and gravel with 4" of solid insulation.

4. Floor to be concrete on grade with mechanical crawl space below grade.

5. Outdoor design: 0° F winter; 95° DB, 76° WB summer.

6. Indoor design: 70° F winter; 75° F, 67° WB summer.

7. Light load calculated at 4w/ft².

9. People load calculated at one person per 100 sq. ft. maximum density.

Based upon this data, a heat loss and heat gain load can be determined. Take into consideration any special constant load equipment such as cooking equipment, hot plates, machinery motors and copy equipment, transformers, and especially computers. All these types of loads represent internal heat gains, along with people and lights, which can be recovered and transferred to the perimeter of the building for use when needed.

The loss and gain will not be calculated since this is standard procedure from existing texts and guides. The calculations are summed up in the following chart:

CHART

	Heat Loss btuh	Heat Gain btuh
1st floor perimeter	74,250	60,000
2nd floor perimeter	74,250	600,000
3rd floor perimeter	74,250	60,000
4th floor perimeter	80,500	65,000
Penthouse	67,500	52,000
1st floor core	—	86,000
2nd floor core	—	112,000
3rd floor core	—	112,000
4th floor core	172,000	165,000
1st floor back perimeter	38,000	33,000
2nd floor back perimeter	38,000	33,000
3rd floor back perimeter	58,000	46,000
TOTALS:	676,750	884,000

These represent 73.7 tons of air conditioning or approximately 300 sq. ft./ton cooling load. A heat loss of 676,500 BTU represents a loss of approximately 9 watts/sq. ft.

As a general rule, a standard office building of reasonable construction and internal usage will average from 250 to 350 sq. ft./ton cooling and 10 watts/sq. ft. heating, using the previously stated design conditions. Naturally, adjustments are necessary for warmer or colder climates or unusual internal gains.

Refer to ASHRAE Standard 90-75 for data on heat transfer, ventilation and usage of glass and walls, building orientation and factors to minimize heat losses and gains.

C. UNIT SELECTION AND LOCATION

Before matching individual heat pumps to the various building loads from the engineering catalogs, a water temperature range for the system must first be selected. In this case, 90° Entering Water for cooling and 75° Entering Water for heating is used. The reason for selection of 90° Entering Water for cooling is that this parameter affords an economical tower selection by using a higher log mean temperature difference. The selection of 75° for heating is arbitrary. The higher the entering water temperature on heating, the greater the unit heat output. However, the unit KW input also increases. This temperature can be a variable and field-adjustable, since the heater operates only on the difference between the inlet and outlet water temperature.

1st Floor Perimeter:

Tenant layout requires 8 private offices. The heat loss and heat gain for the perimeter wall is thus divided by 8 to give 9281 BTU loss for each and 7500 BTU gain for each. From catalog, select an 801-09 at 90° condenser water, giving 8200 BTU cooling capacity, and 10,700 BTU heating at 2.2 gpm of 75° Entering Water.

2nd Floor Perimeter:

Tenant layout requires 5 larger private offices. By the same method, 5 #801-15 are selected.

3rd Floor Perimeter:

Tenant layout requires 6 private offices. By the same method, 6 #801-12 are selected.

4th Floor Perimeter:

Tenant layout requires 8 private offices. So, 8 #801-08 units are selected in the same matter.

Penthouse:

Layout requires sub-division into 5 offices, resulting in the selection of 5 #801-12.

1st Floor Core:

Has an 86,000 BTU gain with no heat loss so, using the same criteria, refer to catalog, Series 823 and select a #V-100.

2nd Floor Core:

By the same method, select a #V-120.

3rd Floor Core:

By same method, select a #V-120.

4th Floor Core:

By same method, select a #V-200. Note this area has a heat loss of 172,000 BTU due to the roof load.

1st Floor Back Core Units:

By same method, using catalog, Series 824 select a 036.

2nd Floor Back Core Units:

By same method, select a #824-036.

3rd Floor Back Core Units:

By same method, select a #824-060.

From the curves in the 3 engineering catalogs, the input KW can be determined and charted. Use the maximum KW per unit for heating or cooling.

Record the pressure drops and convert to feet of head where necessary for later use.

Figure 14 summarizes these selections and data into the equipment schedule for the project.

Other design considerations in the selection of the system are:

- Fresh air requirements and ventilation must meet local codes at the minimum. Maximum comfort may require greater quantities of fresh air where there is heavy smoking or odor generation, but first and operating costs will be increased accordingly.

- Size, location and requirements for fire dampers in supply and return air ducts and penetrations in accordance with local codes and Fire Underwriters' regulations.

- Design for prevention of noise transmission of water, air and machinery through proper insulation of mechanical room and ducting and through selection of equipment to operate at peak efficiency — that is, not oversized for the load.

Of extreme importance is the early determination of availability and cost of electricity, gas, oil and other pertinent utilities and services. This should be thoroughly settled with the utilities. The major consideration is availability at competitive pricing. A determination is necessary as to the most suitable and economical voltage through evaluation of connected load, power availability in the vicinity, transformers, switchgear and electrical distribution to the site as well as within the structure, and consultation with the utility.

Also necessary is a coordination study of the heat recovery equipment and other electrical equipment for compatibility and loads.

The circuitry and power loading in the building can be critical and costly if not properly thought out.

The location of the equipment is determined by the type of building and its uses and requirements. For the window wall with private offices requiring individual thermostat control, one console unit was located in each office to meet the variable heating and cooling requirements.

For the penthouse, one unit was provided for each particular office. The core is a constant load and can be serviced by one unit with one thermostat control. This unit was located in a small mechanical closet on each floor with duct distribution.

The back side of the building has some private offices. But, since the wall was not exposed to the outside atmosphere, a single unit hung from the ceiling for multiple offices was chosen — with a single thermostat control.

Figure 14

A/C equipment schedule

Model #	# of Units	CFM/ Unit	GPM/ Unit	PD./ Unit Ft. of Head	Total GPM	Cooling Cap/ Unit	Total Cooling Cap	Calculated Heat Gain	Heating Cap/ Unit	Total Heating Cap	Calculated Heat Loss	KW Input/ Unit	Total KW Input	Location
801-08	8	385	2.2	5.54	17.6	8,200	65,600	60,000	10,700	85,600	74,250	.795	6.36	1st FL P
801-15	5	515	4.2	5.03	21.0	15,300	76,500	60,000	19,650	98,250	74,250	1.45	7.25	2nd FL P
801-12	6	375	3.1	11.21	18.6	11,200	67,200	60,000	16,000	96,000	74,250	1.16	6.96	3rd FL P
801-08	8	385	2.2	5.54	17.6	8,200	65,600	65,000	10,700	85,600	80,500	.795	6.36	4th FL P
801-12	5	375	3.1	11.21	15.5	11,200	56,000	52,000	16,000	80,000	67,500	1.16	5.80	PH
V-100	1	3500	26.8	16.76	26.8	100,000	100,000	86,000	—	—	—	—	—	1st FL C
V-120	1	4200	31.9	13.49	31.9	117,000	117,000	112,000	—	—	—	—	—	2nd FL C
V-120	1	4200	31.9	13.49	31.9	117,000	117,000	112,000	—	—	—	—	—	3rd FL C
V-200	1	7000	53.6	16.76	53.6	199,000	199,000	165,000	229,000	229,000	175,000	19.20	19.20	4th FL C
824-036	1	1250	9.4	20.48	9.4	35,600	35,600	33,000	44,500	44,500	38,000	3.28	3.28	1st B C
824-036	1	1250	9.4	20.48	9.4	35,600	35,600	33,000	44,500	44,500	38,000	3.28	3.28	2nd B C
824-060	1	2000	16.4	12.77	16.4	62,000	62,000	63,000	83,000	83,000	58,000	6.00	6.00	3rd B C
Totals	39				269.7		997,100	884,000		846,450	676,750		64.49	

*To obtain pressure drop in PSI, divide Feet of Head by 2.3.

Basis: Cooling — 75° DB/67° WB Entering Air, GPM as stated entering @ 90°F.
Heating — 70° DB Entering Air, GPM as stated entering unit @ 75°F.

Code: P = Perimeter Units
FL = Floor
C = Core Units
PH= Penthouse
BC= Back Core Units

D. Ducting

Refer to the section on Zone Analysis for general data on supply and return duct design, discharge grilles and return grilles. However, in this case the following criteria were used:

1. The private offices contain individual perimeter units with their own built-in control.

2. The core units are located in a mechanical closet. The supply air is ducted to the core areas of the building, with the appropriate quantity of supply grilles. The ceiling is used as a return air plenum back to the mechanical closet. In this case, the supply duct does not require thermal insulation. Only on the top floor should the supply duct be insulated.

3. Adequate return air grilles should be located throughout the core for proper return air to the ceiling.

4. The mechanical room is used as a return air plenum with a transfer duct from the hung ceiling into the room. This transfer duct could be insulated and contain a sound trap if necessary. Depending upon fire codes, this transfer duct should contain a fire damper. For sound attenuation, it may be wise to insulate the supply air duct for approximately 10′ to 15′ from the mechanical room. Outside air being introduced can be supplied to this mechanical room where it is mixed with the return air and distributed to the core.

In this example, approximately 3000 cfm of outside air are required and this should be introduced to the 4 mechanical core rooms at approximately 750 cfm per mechanical room. This outside air can be supplied with an outside air fan on the roof. Refer to Section VII-I, CONTROLS, for outside air controls.

Note that, if the pre-calculated outside air/return air mix temperature is in excess of 60° F, then it is not necessary to pre-heat the outside air. 60° F is the point at which the heat pump on the heating cycle may go off on low pressure safety. If the mix is below 60° F, then a pre-heater may be required.

It may be desirable to duct a small quantity of air from the core system into each private office with flexible ducting. In this way some outside air is ducted to each private office as a fixed quantity. Outside air can be introduced at each perimeter unit.

The units mounted in the ceiling use a ducted supply and a free return, using the ceiling as a return air plenum. As pointed out previously, locate the Return Air grille away from the unit for maximum sound control, and provide adequate ceiling access. This ducting need not be thermally insulated except for the 4th floor where the duct is exposed to the roof.

Keep the duct sizing to within reasonable limits in order to avoid air noise problems created by excessive velocity.

E. PIPE SIZING AND ARRANGEMENTS

Before the pipe can be sized for this project, an analysis of the GPM for the units must be made. After the GPM and pressure drops are determined, the pumping arrangement can be selected.

A typical piping arrangement is the one illustrated in **Figure 13**.

The GPM for each unit must be determined from the Product Engineering Catalog for the size unit selected to most nearly meet the design heat loss and heat gain requirements. As previously shown, the units were selected at Entering Water conditions of 90° F for the cooling design, and 75° F for the heating design.

Referring to the Product Engineering Catalog curves, the units were selected to meet the design conditions as follows:

1st Floor Perimeter:

Total heat gain 60,000 BTU and total heat loss 74,250 BTU. Tenant layout required 8 units. Each unit must be capable of producing 7500 BTU cooling and 9281 BTU heating. From the unit capacities of 90° Entering Water and 2.2 GPM each, selection is made of size #801-09 producing 8200 BTU cooling and 10,600 BTU heating. Total GPM required: 8 × 2.2 = 17.6 GPM.

2nd Floor Perimeter:

By same method as discussed above, 5 units at 4.2 GPM each = 21.0 GPM.

3rd Floor Perimeter:

By same method, 6 units at 3.1 GPM = 18.6 GPM

4th Floor Perimeter:

By same method, 8 units at 2.2 GPM = 17.6 GPM

Penthouse:

By same method, 5 units at 3.1 GPM = 15.5 GPM

Core Units:

From Catalog, Series 813 and unit selection on 90° Entering Water, with temperature and loads given, the following selections are made:

V100		26.8 GPM
V120	@ 31.9 GPM × 2	= 63.8 GPM
V200	@ 53.6 GPM × 1	= 53.6 GPM
		144.2 GPM

Back Core Areas:

Refer to Catalog, at 90° Entering Water and given loads to select:

824-036	@ 9.4 GPM × 2	18.8 GPM
824-060	@ 16.4 GPM × 1	16.4 GPM
		35.2 GPM

Note that the GPM selections are based on the cooling load requirements. This is because in general, the BTU load imposed by each unit on the water system, is greatest at summer design conditions. In summmer, the units impose not only the heat gain from conditioned spaces on to the water system, but also the heat of compression of the units' refrigerant systems. This must be done at temperatures that are largely established by the outdoor conditions at the heat rejector. In the winter time, the heat pump rejects the heat of compression to the conditioned space and thus imposes only the heat of absorption on the water system. So, it is certain that a water quantity fixed at summer conditions will be adequate for winter conditions; and in any event, the winter temperature of the water system is controlled by the heater, not by outdoor conditions.

1st Floor Perimeter	17.6
2nd Floor Perimeter	21.0
3rd Floor Perimeter	18.6
4th Floor Perimeter	17.6
Penthouse	15.5
Core Units	144.2
Back Core units	35.2
	269.7 GPM

In this manner, the selection and location of the units and determination of the GPM requirements are completed. It is important to lay out the piping properly as to supplies and returns. Again the building configuration will dictate the most convenient, logical and economical piping arrangement.

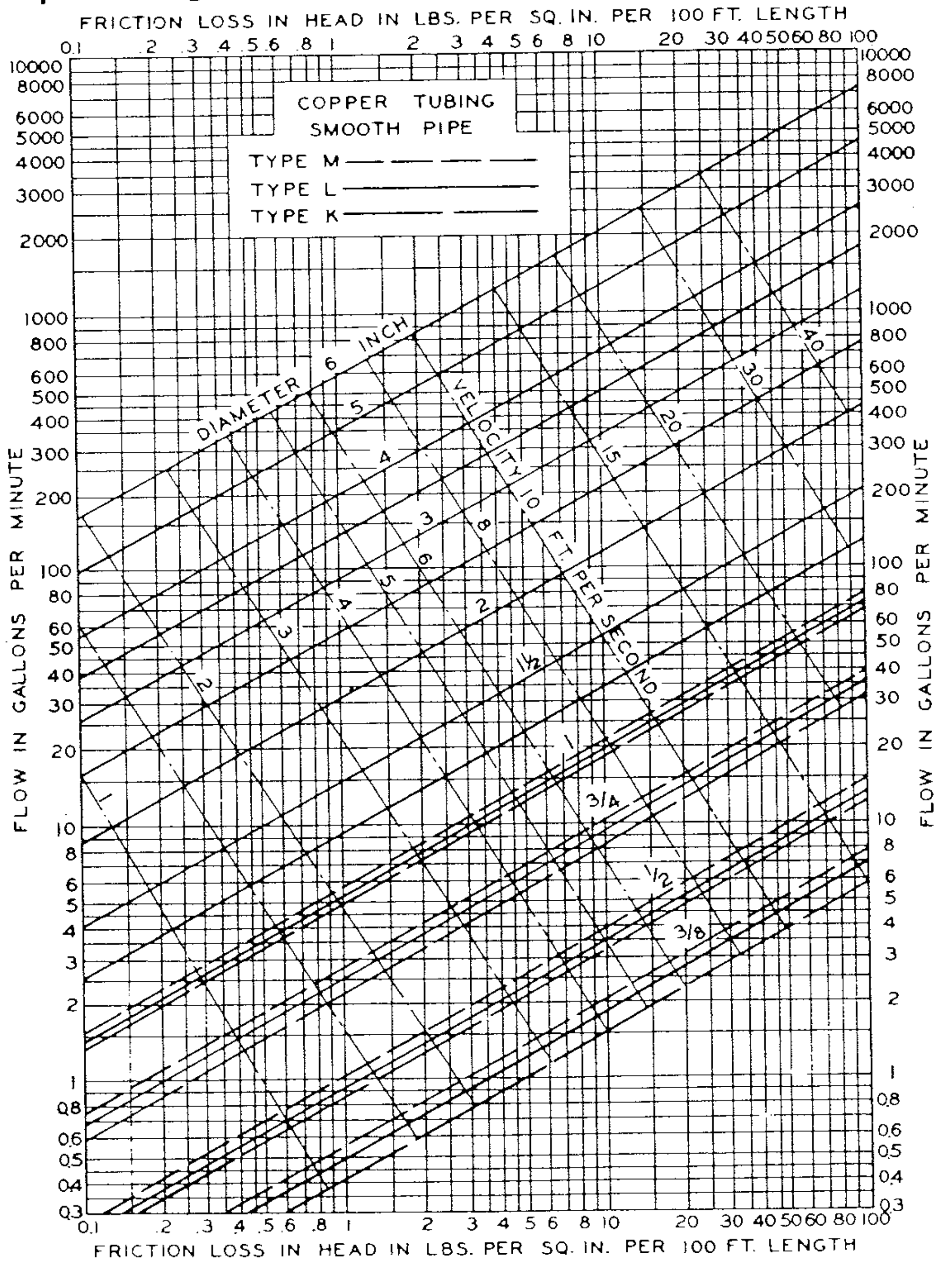
The successful operation of a water source heat pump depends not only on sufficient pressure at the source but upon the proper sizing of water supply and return pipes. Undersized pipes and low water capacity will result in large power consumption and reduced capacity of the unit. It will also result in high head pressures in summer operation and possible freezing of the water in the heat exchanger during the heating operation should the low pressure cutout fail.

Whenever water flows in a pipe, pressure is lost due to friction. In general, the greater the quantity of water flowing through a pipe, the greater will be the loss of pressure due to friction. This loss of pressure is called the friction head of the piping; therefore, the size of pipe required to convey a given quantity of water depends entirely upon the pressure that is available to overcome the friction loss. The pressure drop in different piping due to friction loss is shown in **Figures 15** and **16**. To assure quiet water flow in pipes, velocities of 6 ft. per second, or less, should be maintained wherever possible. Friction losses are either tabulated in "loss of **head in feet** due to friction per 100 feet of pipe" or "friction loss, **pounds/sq. inch** per 100 feet of pipe." One can convert such tables by using one of the two following formulas:

(1) Feet head x .433 x 1.0 (specific gravity of cold water) = lbs. /sq. in.

(2) $\frac{\text{Pounds per sq. in. pressure} \times 2.31}{1.0 \text{ (specific gravity of cold water)}}$ = feet head

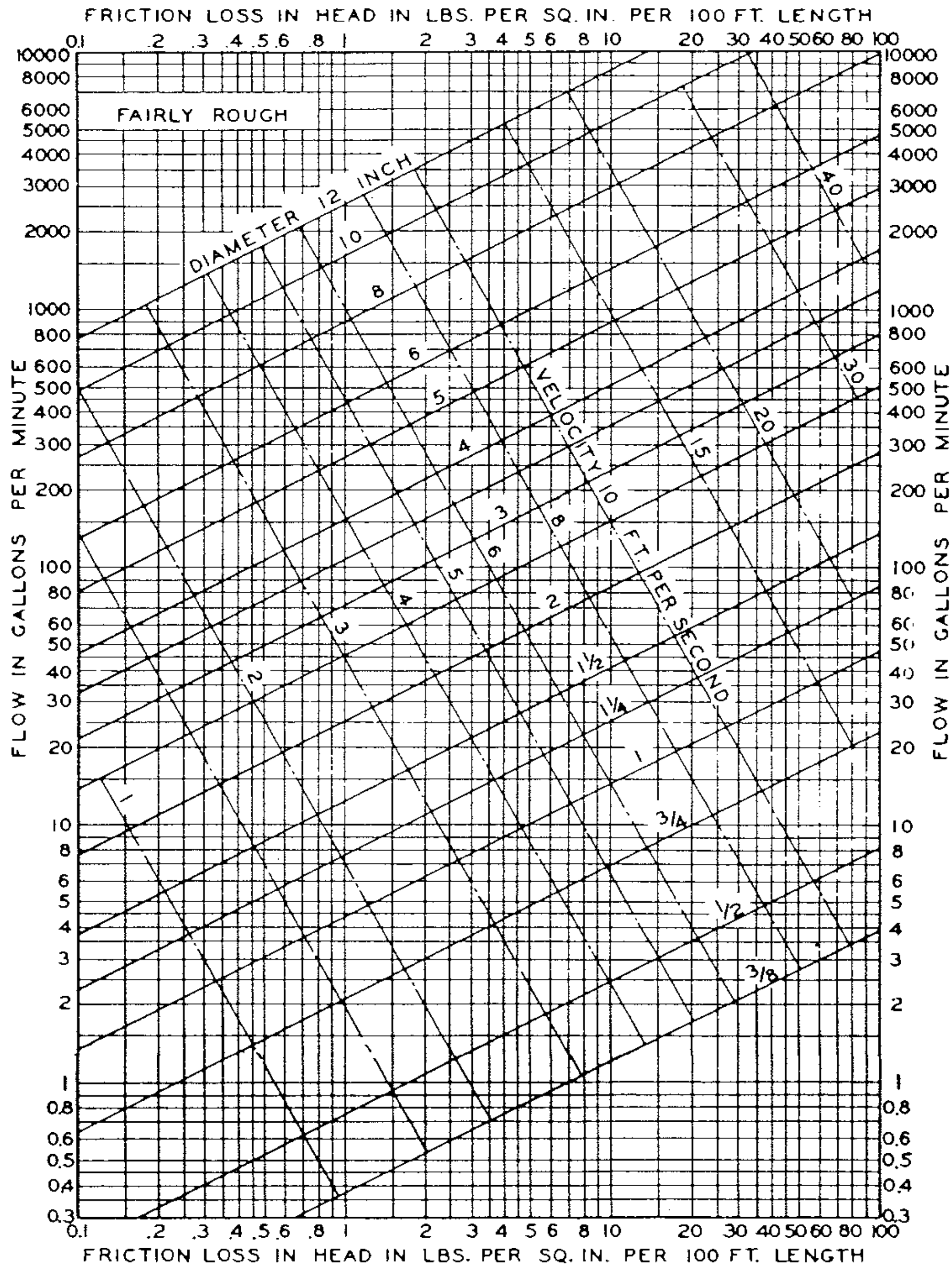
Pipe Sizing Figure 15



Friction loss chart for copper tubing and PVC pipe (use type L copper tubing line for PVC)[1]

[1]R.B. Hunter: Water Distributing System for Buildings (National Bureau of Standards Report BMS79, p. 6, 1941). (Charts extended to flow of 0.30 GPM.)

Figure 16



Friction loss chart for fairly rough pipe (wrought iron and galvanized steel)[1]

[1]R.B. Hunter: Water Distributing System for Buildings (National Bureau of Standards Report BMS79, p. 6, 1941). (Charts extended to flow of 0.30 GPM.)

Figure 17

Valve Losses in Equivalent Feet of Pipe [a,11]

(Screwed, Welded, Flanged, and Flared Connections)

Nominal Pipe or Tube Size (in.)	Globe[b]	60°-Y	45°-Y	Angle[b]	Gate[c]	Swing Check[d]	Lift Check
3/8	17	8	6	6	0.6	5	Globe & Vertical Lift Same as Globe Valve[e]
1/2	18	9	7	7	0.7	6	
3/4	22	11	9	9	0.9	8	
1	29	15	12	12	1.0	10	
1¼	38	20	15	15	1.5	14	
1½	43	24	18	18	1.8	16	
2	55	30	24	24	2.3	20	
2½	69	35	29	29	2.8	25	
3	84	43	35	35	3.2	30	
3½	100	50	41	41	4.0	35	
4	120	58	47	47	4.5	40	
5	140	71	58	58	6	50	
6	170	88	70	70	7	60	
8	220	115	85	85	9	80	
10	280	145	105	105	12	100	
12	320	165	130	130	13	120	Angle Lift Same as Angle Valve
14	360	185	155	155	15	135	
16	410	210	180	180	17	150	
18	460	240	200	200	19	165	
20	520	275	235	235	22	200	
24	610	320	265	265	25	240	

[a] Losses are for all valves in fully open position.
[b] These losses do not apply to valves with needle point type seats.
[c] Regular and short pattern plug cock valves, when fully open, have same loss as gate valve. For valve losses of short pattern plug cocks above 6 in., check manufacturer.
[d] Losses also apply to the in-line, ball type check valve.
[e] For Y pattern globe lift check valve with seat approximately equal to the nominal pipe diameter, use values of 60°-Y valve for loss.

Fitting Losses in Equivalent Feet of Pipe [11]

(Screwed, Welded, Flanged, Flared, and Brazed Connections)

Nominal Pipe or Tube Size (in.)	Smooth Bend Elbows: 90° Std*	90° Long Rad.†	90° Street*	45° Std*	45° Street*	180° Std*	Smooth Bend Tees: Flow Through Branch	Straight-Through Flow: No Reduction	Reduced ¼	Reduced ½
3/8	1.4	0.9	2.3	0.7	1.1	2.3	2.7	0.9	1.2	1.4
1/2	1.6	1.0	2.5	0.8	1.3	2.5	3.0	1.0	1.4	1.6
3/4	2.0	1.4	3.2	0.9	1.6	3.2	4.0	1.4	1.9	2.0
1	2.6	1.7	4.1	1.3	2.1	4.1	5.0	1.7	2.3	2.6
1¼	3.3	2.3	5.6	1.7	3.0	5.6	7.0	2.3	3.1	3.3
1½	4.0	2.6	6.3	2.1	3.4	6.3	8.0	2.6	3.7	4.0
2	5.0	3.3	8.2	2.6	4.5	8.2	10	3.3	4.7	5.0
2½	6.0	4.1	10	3.2	5.2	10	12	4.1	5.6	6.0
3	7.5	5.0	12	4.0	6.4	12	15	5.0	7.0	7.5
3½	9.0	5.9	15	4.7	7.3	15	18	5.9	8.0	9.0
4	10	6.7	17	5.2	8.5	17	21	6.7	9.0	10
5	13	8.2	21	6.5	11	21	25	8.2	12	13
6	16	10	25	7.9	13	25	30	10	14	16
8	20	13	—	10	—	33	40	13	18	20
10	25	16	—	13	—	42	50	16	23	25
12	30	19	—	16	—	50	60	19	26	30
14	34	23	—	18	—	55	68	23	30	34
16	38	26	—	20	—	62	78	26	35	38
18	42	29	—	23	—	70	85	29	40	42
20	50	33	—	26	—	81	100	33	44	50
24	60	40	—	30	—	94	115	40	50	60

* R/D approximately equal to 1.
† R/D approximately equal to 1.5.

[11] *System Design Manual,* Piping Design (Carrier Air Conditioning Co., 1960).

In addition to friction in the pipe line itself, there are always additional losses in pressure due to friction loss in valves, and in fittings such as elbows, tees and valves. The most common way of computing friction losses in fittings is by the equivalent length method. In this method, the friction loss that occurs across a valve or fitting is expressed in terms of the number of feet of pipe of the same size that would produce the same friction loss. The equivalent length for each of several types of valves and fittings is shown in **Figure 17**. For each valve and fitting in the piping system, this equivalent length must be determined and the total of all such equivalent lengths determined. The total equivalent length is then added to the total actual length, and this sum is then used to compute the total friction head of the piping system.

In addition, there is a pressure drop across the refrigerant-to-water heat exchanger of the Climate Master heat pump, the heat rejector and the heater and these must be added to the friction loss of the piping system in order to determine the total pressure drop. To determine the pressure drop in pound/sq. in., refer to the schedule for the example system.

Since the core units are located in the mechanical room in the same location on each floor, these units plus the penthouse will be served from the same supply and return riser circuit. These units are piped as two-pipe direct return. From the previous calculations, the total GPM will be 144.2.

From the same pipe sizing chart, 3½" pipe would be chosen for this application.

The back side core units are fed separately with a supply and return riser circuit requiring 35.2 GPM. From the pipe chart, select a 2" pipe for this duty.

The total system flow is 269.7 GPM. Using the same charts, the piping for the main pump, tower and heater is selected as 5", providing a wat[illegible] velocity of 5 fps and a pressure drop of .6 psi/10[illegible]

With this pipe sizing, flows and arrangement[illegible] the pump selected is discussed in Section [illegible] following selection of the heat rejector and heater.

Note: In this arrangement, a direct retur[illegible] system is used for convenience of piping. Revers[illegible] return can also be used advantageously since th[illegible] reverse return system is easier to balance becaus[illegible] the equivalent length of pipes on both supply an[illegible] return are equal, thus resulting in a logical equa[illegible] flow distribution.

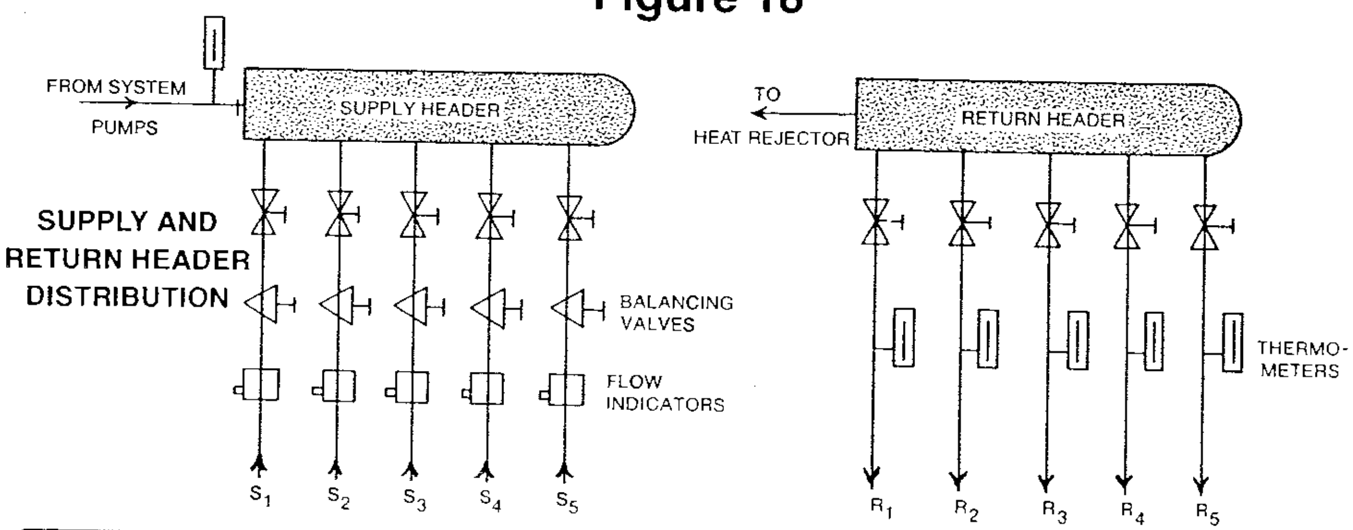
Also, as a convenience in balancing the system a supply and return header distributio[illegible] arrangement can be used as shown in **Figure 18** By placing balancing fittings and flow indicator[illegible] on each supply riser from the header, the wate[illegible] distribution to the system can be accuratel[illegible] determined at one convenient spot. With the retur[illegible] header close by, and with each riser containing [illegible] thermometer, the flow can be double-checked an[illegible] the resultant performance of each loop determined.

Water balancing is necessary to assure tha[illegible] each heat recovery unit receives the prope[illegible] amount of water so the whole loop will operate efficiently. The supply run-outs are balanced by use of balancing fittings and by reading the flow in the flow meters. The amount of water per riser is predetermined by the quantity of units and capacity of units on that riser. With the system in full operation, this balance can be checked by reading the return riser water temperature. The differential between the supply and return riser should be consistently observed.

Individual units should also be balanced. There are several ways to do this . . .

1. By temperature differential between supply and return;

Figure 18



2. By balancing cocks and circuit setters;

3. By pre-calibrated flow orifices

Since the water temperature in the loop never drops below the dew point and the piping is basically in the conditioned space, there is no insulation required on the piping.

In general, water supply pipes used for heat pumps are of wrought iron, galvanized steel, or copper. More recently, plastic pipe has been applied with excellent results. PVC is not affected by chemicals in the same way as metal pipes. Corrosion of metal pipe is usually electrolytic; PVC is a non-conductor and is immune to galvanic or electrolytic attack. PVC also effectively resists a large number of oxidizing chemicals and most of the troublesome acids. It offers excellent resistance to alkalis, salt solutions and many other organic compounds. Pipe is ready to install and can be cut with a handsaw and joined quickly to fittings by solvent cementing, reducing installation costs considerably.

Plastic piping, however, has certain limitations on temperature and pressure. In the normal temperature ranges of 50° to 105° encountered in a Heat Recovery System, the pressure limit is about 112 psi. In low rise buildings, the system pressure is usually within these limits. In high rise structures, a careful analysis of the static and dynamic pressures in the system should be made.

Caution should also be exercised in the use of plastic where shock could occur such as at valves and fittings. High impact schedule 40 and 80 PVC piping is recommended for heat pump use.

The fact that PVC is not a conductor makes proper electrical grounding of the heat pump unit mandatory.

When plastic piping is used, a minimum amount of flushing and cleaning is required compared with that required for steel and iron. In general, plastic piping will be approximately 10% to 15% cheaper overall in systems requiring pipe between 4" and 8" diameter. In piping below 4", the cost difference between copper and plastic is small considering both material and labor. Above 8", the fittings for plastic become quite expensive and consideration should be given to steel. In high rise structures plastic can be used on the upper floors; and steel can be used on the lower portions where pressure heads are larger.

In some localities, codes prevent the use of plastic piping on hydronic heating applications because of the operating temperatures in the 200° F range. So it is important to make certain that the heat recovery water system is understood by the authorities as a condenser water circuit and properly classified accordingly.

In all cases, the piping system should include the following important items:

1. Air venting of the system at the highest point in the system, as well as at the cooling tower and the top sections of risers.

2. A system strainer, either separate or as part of the pump suction diffuser, should be included for removal of foreign substances, regardless of the type of piping used. The strainer should have a drain-off assembly. (Strainers at each unit are not necessary.)

3. Where possible, riser drain-offs should be included.

4. Where possible, all two-pipe and one-pipe horizontal loops should contain positive closure valves and drain-off tees for loop isolation.

5. Condensate lines must have proper pitch for condensate removal. Trapping of condensate at horizontal and vertical units is recommended. Trapping of console units is not necessary.

6. Circuit setters for flow balancing in run-outs and at units is usually optional.

7. All units should be piped with positive hand shut-off valves and unions for unit removal.

The perimeter units in this example, are fed with a supply riser with 4 loops connected to a return riser. This supply and return riser will be required to handle a total of 74.8 GPM. Using a pipe sizing chart, a 2½" riser is selected, providing a velocity of 5 ft. per second and a friction loss of 1.5 psi per 100' of pipe. The pipe riser will be reduced accordingly as each loop is taken off; and the return riser will be increased as loops are added, based on the common friction method.

Note: in this case, a 2" riser will be used at 6 ft./sec. after considering the following:

1. 2½" pipe and fittings are usually not stock items. They require a special order and will possibly be much higher in price.

2. The added head loss and resultant pump selection will not be excessive.

3. Such short runs of 2" pipe will not materially affect noise. Therefore, the actual friction loss will be 2.8 psi/100' of pipe.

Using the same methods, the risers for the Core Units can then be selected.

F. HEAT REJECTOR SELECTION AND OPTIONS

Historically, the water source heat pump has proven to be very successful in absorbing and rejecting the heat to water obtained from wells. This concept is still widely used for residences and small buildings generally requiring only one unit in areas where chemically compatible water is available from wells, and is often used with optionally available cupro-nickel refrigerant-to-water heat exchangers. The efficiency derived from this type of application is ideal, in that there is direct transfer from refrigerant to the underground water. Further, this water remains at a relatively constant temperature throughout the year regardless of outside air temperature variations, and thus serves equally well as a heat source or a heat sink, without the need for supplemental heat or heat rejection.

However, such water is not generally available for most installations and, even if it were, its use becomes unfeasible for large multi-unit projects. Accordingly, other means of heat rejection are normally used on multi-unit projects.

The purpose of the heat rejector in the Heat Recovery System is to reject heat from the water whenever the temperature of the water rises above a predetermined level. In most latitudes, there is a substantial number of operating hours when heat removed from the core of the building can be "pumped" to the perimeter areas where heat is needed. Under these conditions, the operating water temperatures will probably remain within a range of 60° F to 95° F, and therefore there would be no requirement to add heat to, or reject heat from, the water. However, as outside temperatures rise, more and more units switch to cooling, thus rejecting heat, for which there is less and less need, to the water system, and so the operating water temperature rises. As the process continues the temperature rises to the point where heat must be rejected from the water to maintain it within the established operating limits. This section will discuss the method of selection of the type and size of heat rejector.

In order of efficiency, the types of heat rejectors would be:

1. An open cooling tower where the heat is rejected directly to the air. The use of this type of tower is required where there is a high outside summer design wet bulb. With proper chemical treatment of the loop water, it has been successfully applied in many applications where the air is free of severe contamination.

2. If a source of water prone to chemical scaling but with a relatively constant temperature is available (such as a well, lake or stream), then a water-to-water heat exchanger would be used. The shell side would contain the closed water system for the individual units. The well or alternate source of water would circulate on the mechanically cleanable tube side.

3. In climates where the summer wet bulb is moderate, a closed circuit tower or evaporative cooler is used. In this method, the water is circulated in a series of tubes in the tower and the heat is transferred to a water film on the outside of the tube. The water film is created by spray nozzles or troughs and circulated by a pump with the evaporative action enhanced by a fan.

In order to size the heat rejector, it is necessary to determine the maximum amount of heat that must be rejected — a condition which would occur when all units are in operation in the cooling mode. Aside from this information, flow rates and temperature ranges for which the loop system is designed would be necessary.

In this particular example, a closed circuit evaporative cooler is chosen, since there is no usable lake, pond or well water available. The open tower was ruled out due to local atmospheric conditions which would probably have caused excessive problems in cleaning and corrosion within the closed loop system.

From the previous section a total flow rate of 269.7 GPM was determined. This is the total amount of water to pass through the heat rejector.

The closed circuit heat rejector will be a continuous water flow arrangement, summer and winter. Note that the calculations were based on 90° F entering water temperature to the heat pump system. This is the temperature **leaving** the heat rejector.

Since the climatic conditions for this example set the design wet bulb at 76°, the only other unknown for proper cooler selection will be the **entering** water temperature to the rejector which corresponds to the water temperature **leaving** the heat pump system.

Refer to the catalog, Series 801; 824; and V at the 90° entering water (EW) temperature and GPM used to determine the leaving water (LW) temperature of each size unit at the **rated** load. Note the rated load may be higher than the load required to the job.

16	801-08 @	2.2 GPM 90° EW = 99.7° LW temperature
11	801-12 @	3.1 GPM 90° EW = 99.6° LW temperature
1	V-100 @	26.8 GPM 90° EW = 100° LW temperature
2	V-120 @	31.9 GPM 90° EW = 100° LW temperature
5	801-15 @	4.2 GPM 90° EW = 99.7° LW temperature

1	V-200 @	53.6 GPM 90° EW = 100° LW temperature
2	824-036 @	9.4 GPM 90° EW = 100° LW temperature
1	824-060 @	16.4 GPM 90° EW = 99.9° LW temperature

Note that the weighted average final temperature or a temperature differential (DT) of 10° (100° L.W. - 90° E.W. = 10°)

Load Diversity

The calculated heat gain of the building is 884,000 BTU. The installed capacity of the equipment is 997,100 BTU which results in a load diversity of .886.

884,000 BTU gain actual = .886
997,100 BTU installed

The leaving water temperature with a load diversity of .886 can be calculated thusly:

Load Calculated leaving water temperature: (.886 × 10) + 90° = 98.86°.

Operating Diversity

These calculations for matching unit diversity to load are based on the assumption that all of the units will be operating at the same time in meeting the calculated heat gain loads at **maximum** outside design conditions.

A diversity can be used in this condition. Maximum design performance occurs for only short periods. Full capacity operation of equipment is rarely required.

Use of such diversity should be made with caution and the result of experience and a full understanding of the building's operations and functions.

Operational diversity depends heavily on occupancy and time of occupancy and is a weighted judgment factor. Operational diversity can also be planned by use of load shaving devices which will limit the demand to certain predetermined load limits.

Also, based upon location, and the number of actual hours in the high wet bulb ranges, diversity may or may not be used in the cooler selection.

In this case, select an arbitrary .9 diversity for building operation and call it an Operating Diversity.

In selection of the cooler, the primary consideration is the smallest size and most efficient unit, since both first cost and operating cost are major factors.

In general, the best cooler selection will be obtained when using the largest Log Mean Temperature Difference (LMTD) as possible within practical system design.

98.86° - 90° = 8.86°
Operating Diversity:
(.9 × 8.86) + 90° = 7.97° + 90° = 97.97

Based on these two diversities, we will select the heat rejector to produce 90° Leaving Water with a 97.97 Entering Water at 76° WB and 269.7 GPM. From manufacturer's catalog the following is derived:

Range: 97.97° - 90° = 7.97
Approach: 90° - 76° = 14.0°

From the curves of the Evaporative Cooler Catalog for 269.7 GPM, the pressure drop is 9 psi. A 15HP fan motor and a ¾HP spray pump motor are required.

Refer to **Figure 19** for recommended piping of the cooling tower. Also refer to manufacturer's installation procedures in all cases. The cooler can be installed inside with ducted air inlet and ducted outlet, or the room can be used as an inlet plenum with ducted outlet. For outside installations in moderate and cold climates, the cooler should be equipped with discharge cones with motorized closure dampers. This will prevent convection blow-through when the cooler is not operating and can also be used as one step in the capacity control sequence.

The purpose of discharge cones is to allow the discharge dampers to be smaller and less costly. Full size cooler dampers can be used but become quite expensive and difficult to operate. Refer to the evaporative cooler manufacturer's data when this approach is used.

If the cooler manufacturer's capacity control is used in lieu of the Climate Master control, the cooler will be equipped with fan scroll dampers. In these cases, the discharge cones and dampers may be optional in mild weather climates, but are required for heat loss protection in colder climates.

An additional requirement for colder climates is insulation of the coil section as well as the discharge cones in order to prevent excessive heat loss from the circulating water to the atmosphere. Such heat loss would otherwise have to be made up with supplementary heat. Further, the sump section should contain electric heaters to keep the spray water above freezing. In lieu of sump heaters, a maintenance program should be set up to drain the sump during the winter months.

In all climates, the evaporative cooler should contain such necessary items as overflow drain and make-up water supply.

The piping to the cooler should contain shut-off valves. Each outlet on the coil section should contain automatic air vents. In case a balanced header arrangement without valves is used, a positive means should be provided for shutting off the header and draining the coils.

Supply and return piping plus water make-up should be heat traced and insulated for outdoor installation where freezing could occur.

Freeze-up protection can also be provided with automatic dump valves on the tower which are motorized and spring loaded, designed to open whenever the outside temperature goes below freezing. This type valve is used when the system is bypassing the tower with manual control.

Water Treatment

Water treatment is recommended on the sump or spray water side of the cooler. However, consult local water treatment companies as to recommendations. Normally, the closed system does not require water treatment once the final fill has been treated and neutralized to the proper PH levels.

Alternate Cooler Applications

As mentioned earlier, an open cooler can be used on a Heat Recovery System, provided that water treatment and filtration are diligently maintained at all times. Even so, the use of an auxiliary heat exchanger for an open tower application is suggested, unless the atmospheric conditions are carefully analyzed and determined to be acceptable.

In this case, a shell and tube heat exchanger can be used with the tower water circulating through the tubes (so they can be periodically cleaned) and the closed system water through the shell. Refer to **Figure 20.**

An additional pump is required to circulate the tower water through the tube side of the heat exchanger. In selecting the heat exchanger, allow a scaling factor of .001. Realize that an additional efficiency loss will be incurred.

In such an installation, it may not be necessary to provide freeze-up protection on the tower, since there are no tubes exposed to the atmosphere. The sump may be optionally heated to keep the water from freezing, or the sump can be drained and refilled as required or the cooler sump can be kept continuously drained by returning to an inside sump.

This type of arrangement allows the use of smaller towers. They can be remotely located from the building. Control is necessary for the tower operation and can be accomplished with a temperature sensor in the system line. This will leave the heat exchanger shell, with a throttle valve in the tower water line, to maintain temperature control. Or the sensor can be arranged to start and stop the tower pump to accomplish the same result.

In most cases, the combination of open tower, heat exchanger and 3rd pump will be more expensive than a closed circuit cooler.

The operating cost will be about the same. The open tower fans will require less horsepower (HP) but the added tower pump HP will usually equal the closed circuit higher fan HP. An evaluation should be made on a job-for-job basis. The cooler usually accounts for only about 3 to 5% of the total HVAC operating cost. The prospective savings are negligible.

Figure 19

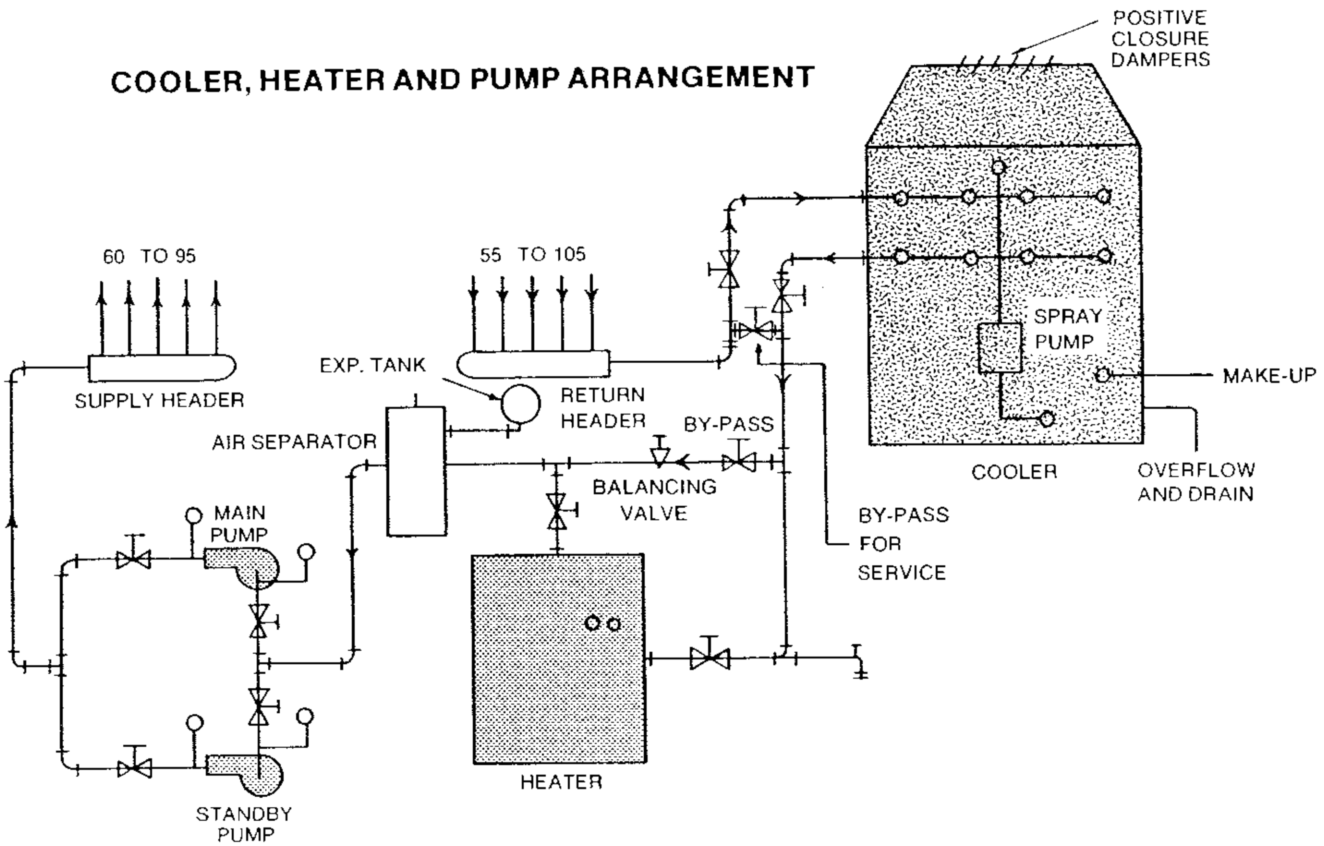
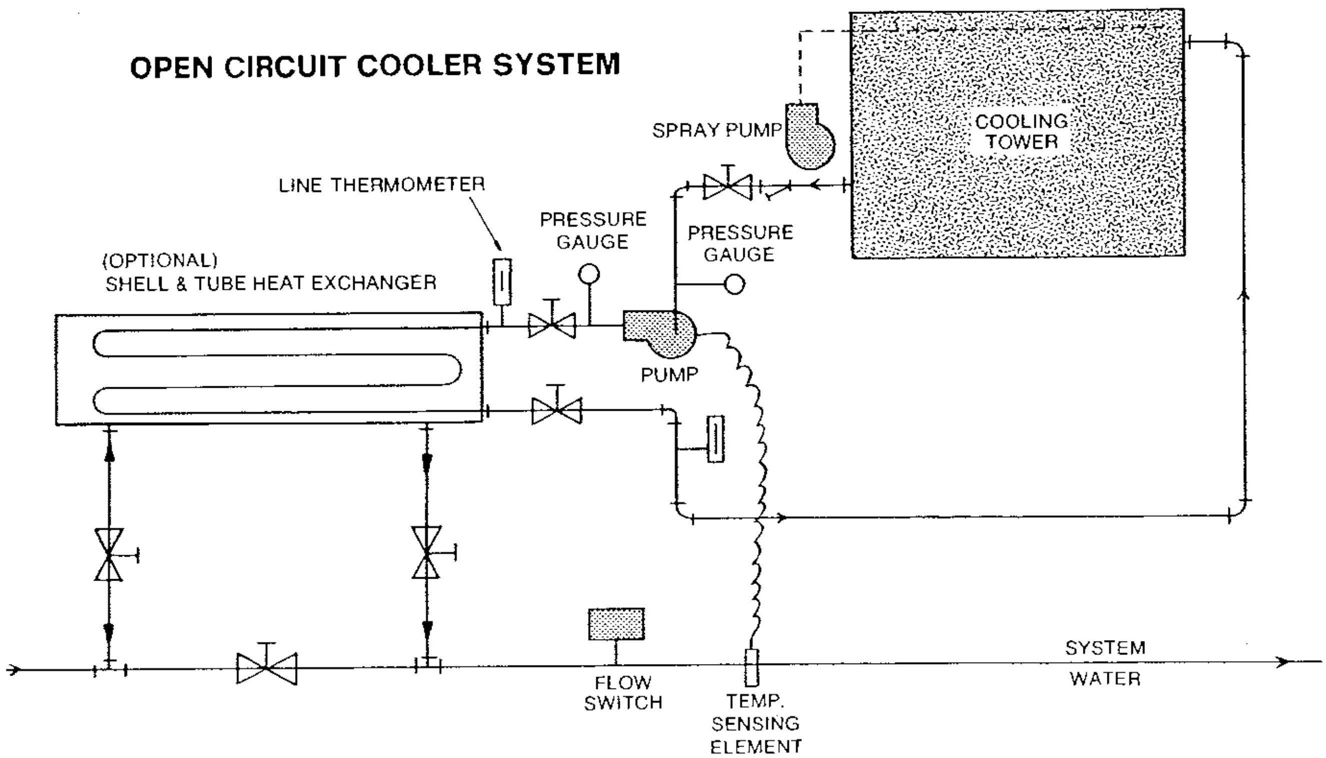


Figure 20



G. HEATER SELECTION AND OPTIONS

During certain periods of operation when the building's heat requirements exceed the cooling requirements, additional heat may be needed. This normally occurs in sustained very cold weather when most of the heat recovery units are on the heating cycle and are absorbing heat from the system water loop. The heater is required to raise the temperature of the water loop whenever it drops below the minimum design temperature.

Typically, the heaters have self-contained temperature gauges, pressure relief valves and factory-wired programmed controls.

The controllers are designed to regulate the water temperature at a desired design temperature, and include sequencing controls for step control at the design temperature. Among the standard controls normally furnished with the heater is a low water flow sensing switch which deactivates the heater.

This heater could be of several types, depending on what source of fuel is readily or economically feasible. Specifically, it can be any of the following:

- Electric Heater
- Oil Fired Heater
- Gas-Fired Heater
- Heat Exchanger — if a central source of either steam or hot water is available
- Solar Collector — usually as an energy-conserving supplement to one of the foregoing types of heaters.

Normally, the full system water flow is not maintained through the heater. Instead, a balanced bypass is required.

This section will deal with the selection of the heater for the example system. In selecting the heater, first determine the type of fuel available. In this case an electric heater is chosen because adequate electricity is available at 4¢ per KWH, and because the electric heater:

1. Eliminates air pollution.
2. Eliminates the need for a chimney or stack.
3. Is lower in first cost than oil or gas heaters.
4. Requires lower maintenance cost.
5. May be more costly to operate, depending on the cost of oil or gas, but this disadvantage is diminished by the fact that a substantial portion of the heat required is supplied by the heat pumps.

Naturally, full evaluation of fuel cost, first cost and application will be necessary on a job-for-job basis.

The Heat Recovery System operates in a temperature range from 60° to 95°. Within these limits, no additional heat is required.

To calculate the BTU of the heater proceed as follows in the example.

Select the heater for the maximum requirement, which is to maintain the building at 70° with 0° outside on the Unoccupied Cycle — that is, when there are no other sources of heat such as lights, people, equipment and solar. The effect of night set-back on the heater selection will be discussed; as will the effect of daytime "Operational Diversity."

Using the example building, the heater is selected as follows:

Step 1
From Section VII-B, the calculated design heat losses of the building are 676,750 BTU.

Step 2
From **Figure 14** in Section VII-F — calculated heat loss figures are shown as well as unit heat output totals. Use the unit heat output totals based on the GPM shown at 75° F for only those units exposed to the outside surfaces of the building. The control sequence cycles the interior core equipment to OFF on the Unoccupied Cycle and allows only the perimeter or top floor core units to operate on night thermostat.

Therefore, based on this data, if all the units designated are running to maintain the design conditions, the **total output** of the **installed** equipment is as follows:

1st Floor Perimeter	85,600 BTU
2nd Floor Perimeter	98,250 BTU
3rd Floor Perimeter	96,000 BTU
4th Floor Perimeter	85,600 BTU
Penthouse	80,000 BTU
4th Floor Core	229,000 BTU
1st Floor Back Perimeter	44,500 BTU
2nd Floor Back Perimeter	44,500 BTU
3rd Bloor Back Perimeter	83,000 BTU
Total	846,450 BTU

Step 3
The total output is .... 846,450 BTU
The total heat loss is .... 676,750 BTU
Therefore, the Installed Diversity Factor is .799.

$$\frac{676,750}{846,450} = .799$$

Step 4
With all the above designated heat pumps running to accomplish the total output a certain amount of heat is absorbed from the circulating water. This is called Heat of Absorption. The Heat of Absorption of a unit is always less than the heat output of the unit because the latter is the sum of the Heat of Absorption and the Heat of Compression.

From the Product Engineering Catalog on Series 813, 814, and V at 75° Water and the GPM from **Figure 14** in Section VII-F, this Heat of Absorption can be summarized as follows:

Area (Abbreviated)	Unit Selection	Heat of Absorp. (BTUH)	Number of Units	Total Heat of Absorption (BTUH)
1st Fl P	801-08	8,000	8	64,000
2nd Fl P	801-15	14,700	5	73,500
3rd Fl P	801-12	12,000	6	72,000
4th Fl P	801-08	8,000	8	64,000
Pths	801-12	12,000	5	60,000
4th Fl C	V-200	163,000	1	163,000
1st FlBP	824-036	33,000	1	33,000
2nd FlBP	824-036	33,000	1	33,000
3rd FlBP	824-060	61,000	1	61,000
			Total	623,500

Step 5
The Total Heat of absorption computed in Step 4 at design conditions is an instantaneous rate which can be modified by the Installed Diversity Factor of .799.

623,500 BTUH × .799 = 498,176 BTUH

$$KW = \frac{498,176 \text{ BTUH}}{3,413 \text{ BTUH per KWH}} = 145.96 \text{ KW}$$

Step 6.
A heater of 145 KW could be selected. This represents the amount of heat which will be added back into the water to offset the heat absorbed by the heat pumps to meet the design conditions during the unoccupied cycle.

Night Set-back

If a night set-back schedule is used with set-back to 60°, the heat loss calculations could be reduced by approximately 8.5%. Therefore:

Heat Loss:

676,750 BTUH -(8.5% of 676,750 BTUH) = 619,226 BTUH

Installed Diversity Factor:

$$\frac{619,226 \text{ BTUH}}{846,450 \text{ BTUH}} = .732$$

Total Heat Absorbed:

623,500 BTUH (from Step 4)

Actual Heat Absorbed:

623,500 BTUH × .732 = 456,402 BTUH

$$KW = \frac{456,402 \text{ BTUH}}{3,413 \text{ BTUH per KWH}} = 133.7 \text{ KW}$$

A 130 KW heater can be selected, thus saving an installed 15 KW.

With night set-back the building can be warmed up in the morning without the need to oversize heater capacity and without power surge by staging the time clocks for random start-up per zone, floor, or unit at 15-minute intervals, beginning an hour or more prior to opening time.

Operational Diversity

In this particular example, it can be determined that during the occupied cycle, several factors begin to affect the need for the heater to add heat to the water. For instance in the core on the 1st, 2nd, and 3rd floors, the units can satisfy the requirements by operating on fan and ventilation only, thus neither adding nor subtracting heat from the water. This classifies these units as "neutral". However, with the space in full operation, the people and lights load would require the units to switch to cooling and, as shown in **Figure 14** of Section VII-F the equipment will then be adding heat to the water. This heat is called Heat of Rejection and becomes usable heat for the perimeter equipment to absorb to combat the heat losses.

By referring to the Product Engineering Catalog tables, it can be shown that the heat rejected to the water loop when these units are on cooling is approximately as follows:

Area	Unit	Heat of Rejection BTUH
1st Floor Core	V-100	134,130
2nd Floor Core	V-120	158,980
3rd Floor Core	V-120	158,980
Total		452,090

The Calculated Heat Gain = 310,000 BTUH
The Total Cooling Output = 334,000 BTUH

This shows that, for practical purposes, the unit output has been sized very closely to match the load and the diversity is negligible.

This means that the actual heat being **added** to the water, if the machines are working under full capacity to meet the interior heat gains, is equal to 452,060 BTUH.

Note that if all the perimeter units are operating at maximum capacity to combat the heat losses, the heat absorbed from the water would be 498,176 BTUH. However, this load is based on the Unoccupied Cycle with no lights, people, or sun load. Taking into consideration a 75% diversity for the lights, people and sun, the heat absorbed from the water would be reduced accordingly . . .

498,176 BTUH × .75 = 373,632 BTUH

This example thus shows that the core equipment on cooling rejects more than enough heat (452,060 BTUH) to the water to make up for the heat being absorbed from the water (347,949 BTUH) by the perimeter equipment. When this occurs there is no need for the electric heater to be energized.

This also demonstrates that the selection of a heater, in most cases of buildings with a core, is based on the losses for the Unoccupied Cycle. As mentioned previously, each structure will have to be analyzed thoroughly as to orientation, use, lights and construction. For example, such an analysis for hospitals or other institutions with 24 hour occupancy will usually show that a much smaller installed heater is required.

Even in this example, the heater could be further reduced in size by analyzing the weather data as to the number of times and hours the outside design temperature of 0° F occurs. If the percentage of time is small, and usually occurs at night, then a "Judgment Diversity Factor" can be utilized. If the building should sub-cool a few degrees once or twice when such conditions occur — no damage would be done and no discomfort experienced.

In this particular example, it was judged that the heater requirements could be reduced by 30% without any jeopardy to the structure or conditions, and a 90KW heater is selected.

The following diagrams illustrate several methods of heater installations.

Figure 21. Illustrates an electric heater. Since electric heaters are instantaneous, they add heat only when required. A fixed quantity of water circulates continuously and the remainder is by-passed and balanced with a balancing fitting to adjust the mix water temperature to the system. Illustrated are suggested hook-up for make-up water, expansion tank, air control, and pressure regulator. Expansion tanks are small in comparison to conventional Hot Water systems.

Figure 22. If there is a source of steam or hot water from a central plant, the Heat Recovery System heater can consist of shell and tube heat exchangers with the heat pump loop water in the tubes and the hot water or steam in the shell. Control is accomplished with steam valves or hot water valves actuated by the control in the system water supply.

Figure 23. When oil or gas fired package boilers are used, the boiler water temperature must be maintained at a pre-set temperature, usually a minimum of 140°. With a balanced fixed by-pass, the control valves modulate to allow loop water to mix with the boiler water to maintain a proper mix supply water temperature.

A safety cut-off is used to prevent overheating if a malfunction occurs in the burner.

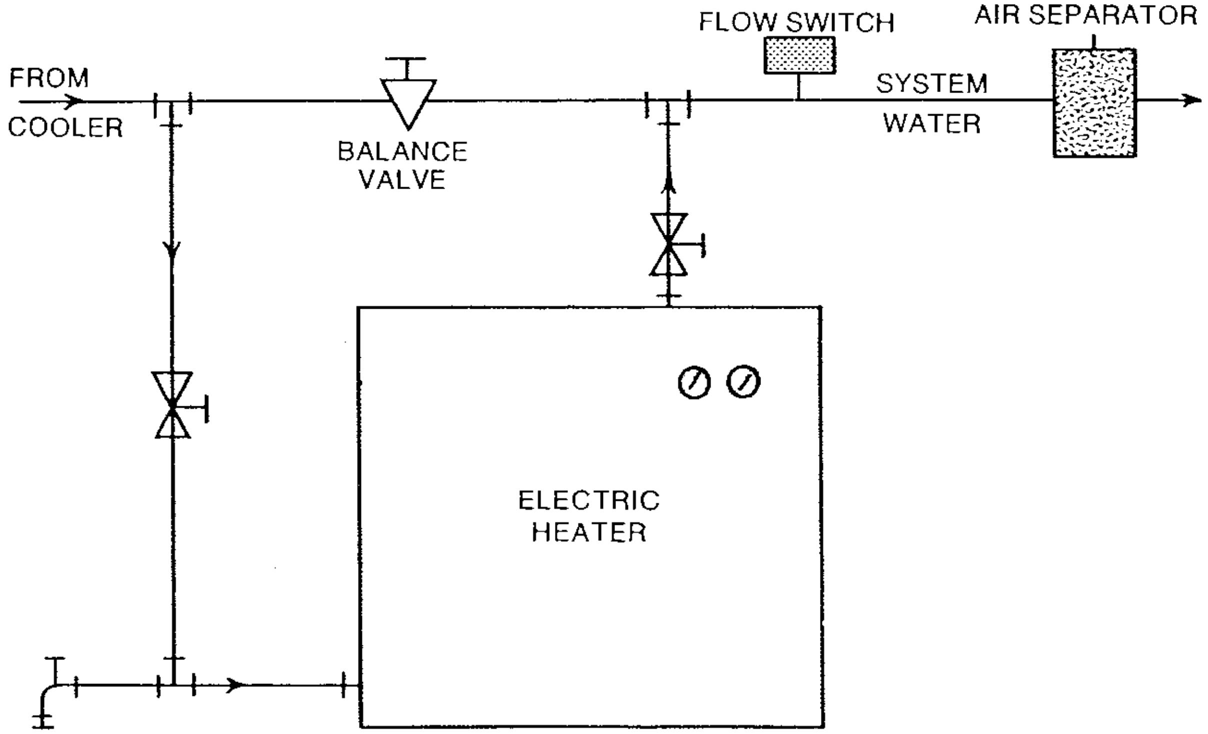
A separate circulator can be used in lieu of the control valve wherein the circulator would be controlled by the mixed leaving-water temperature.

Not shown, but also used quite often, are module package oil or gas fired boilers. The system of water circulation is identical to an electric boiler arrangement. The boilers are sequenced on and off on command of a temperature controller in the leaving-mixed-water line.

Figure 21

HEATER ARRANGEMENT FOR ELECTRIC HEATER

AIR SEPARATOR EXPANSION TANK CONNECTIONS



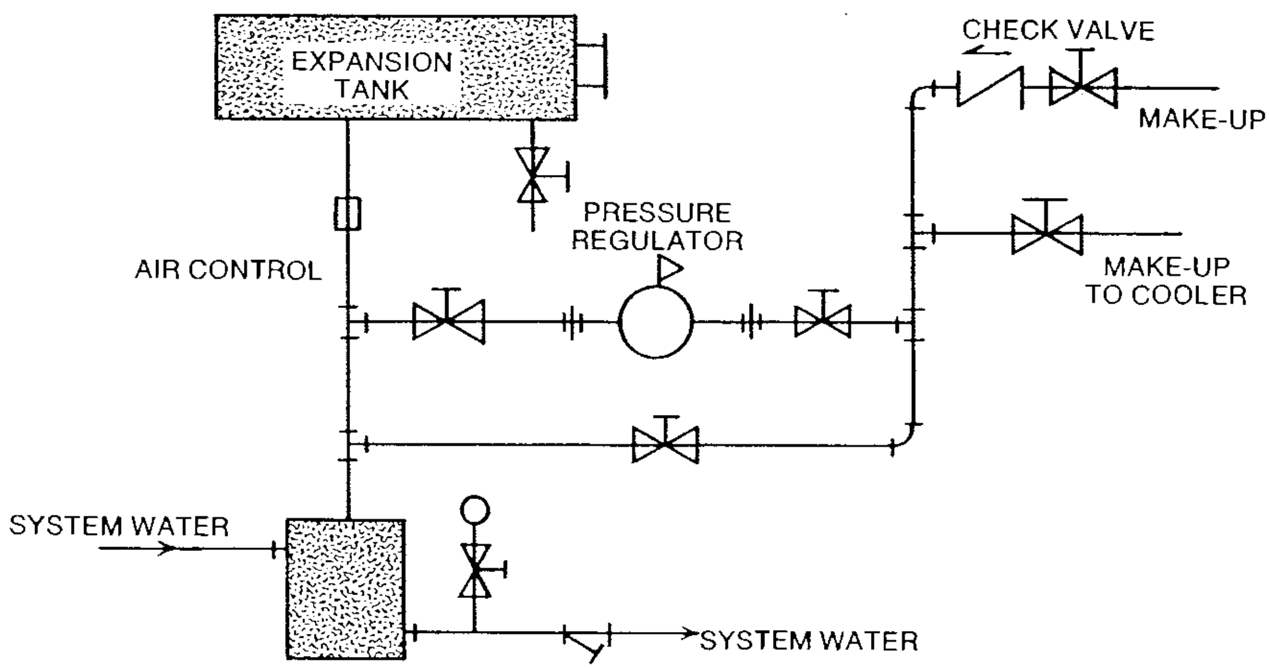


Figure 22

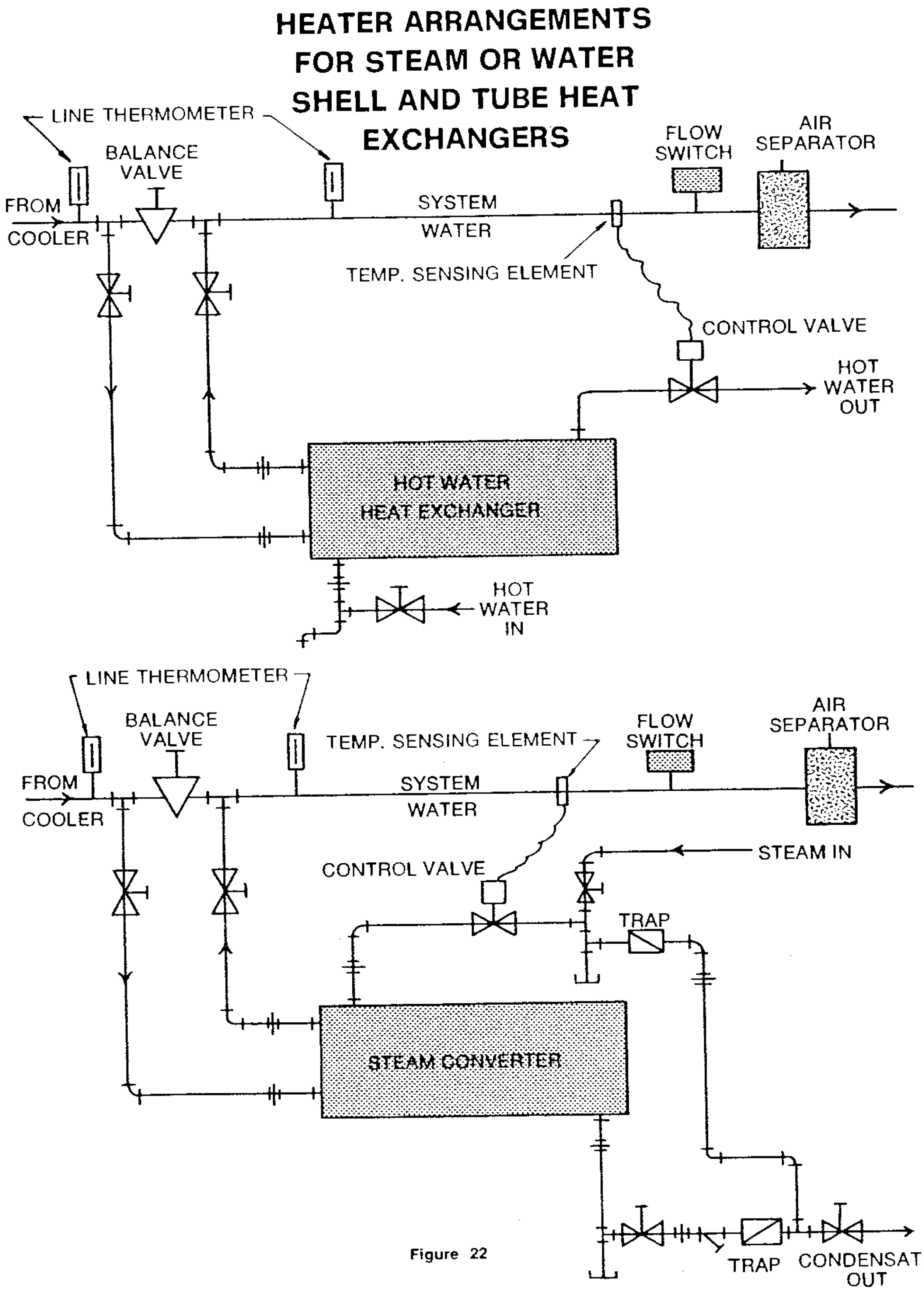
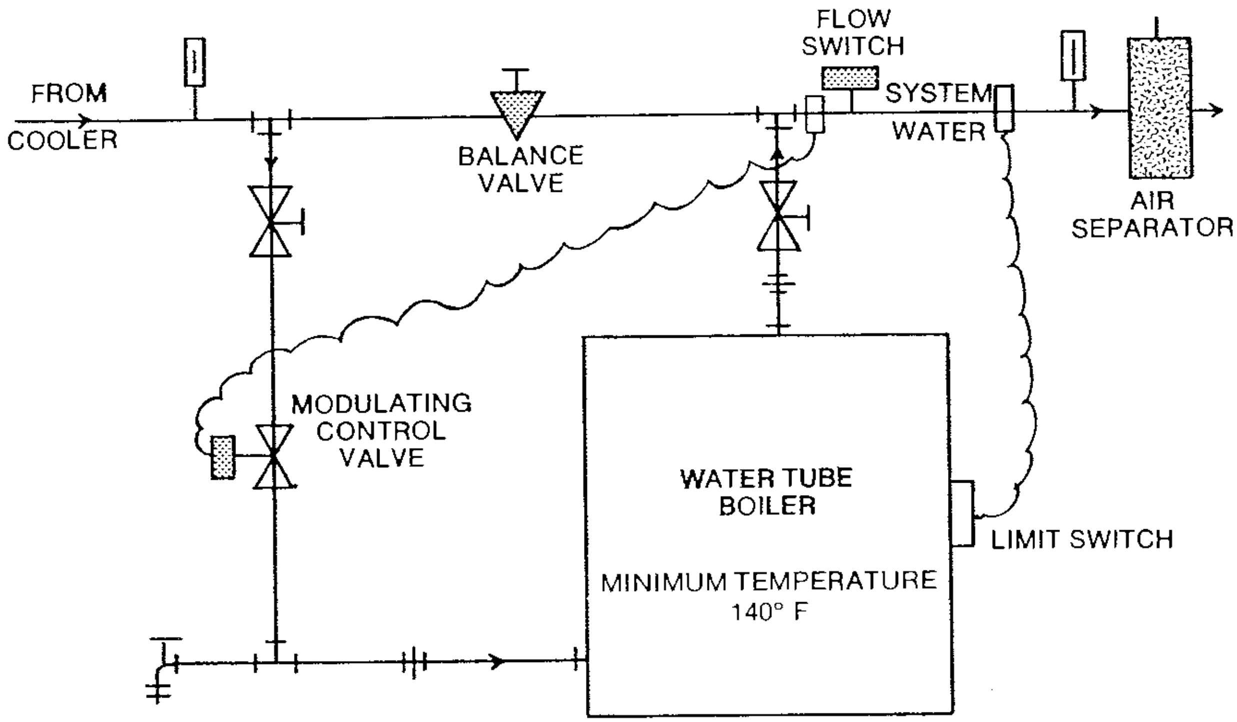
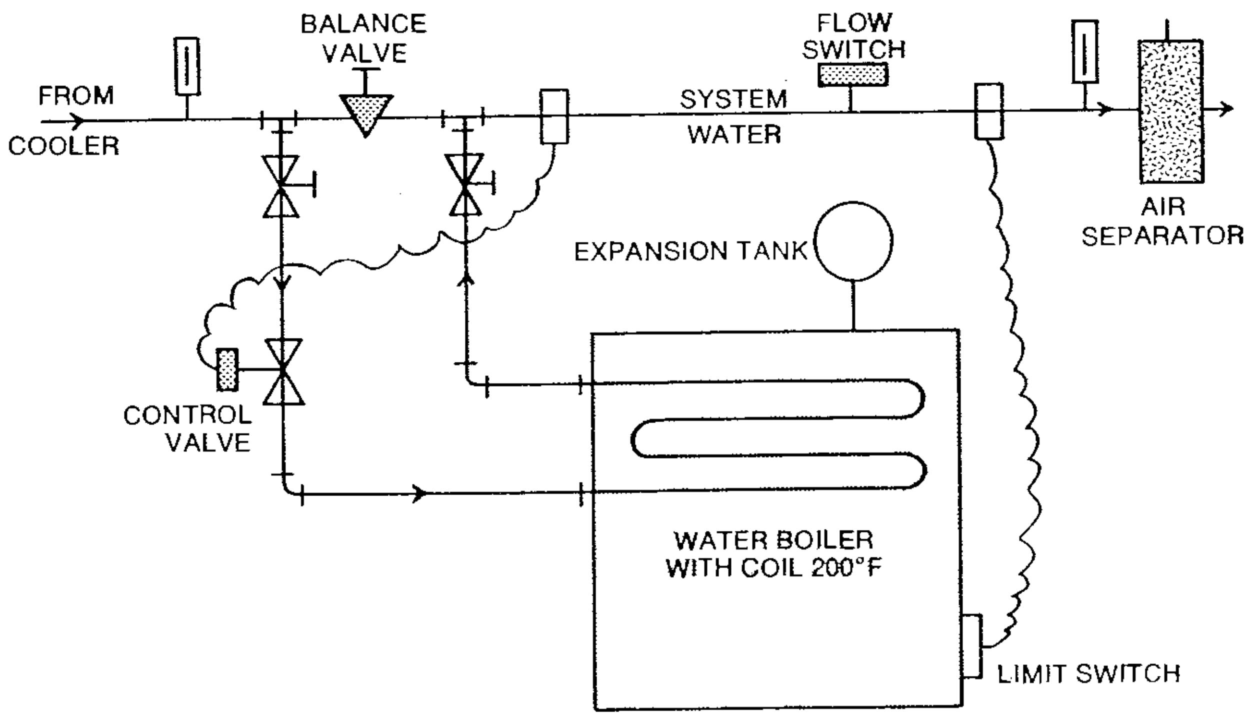


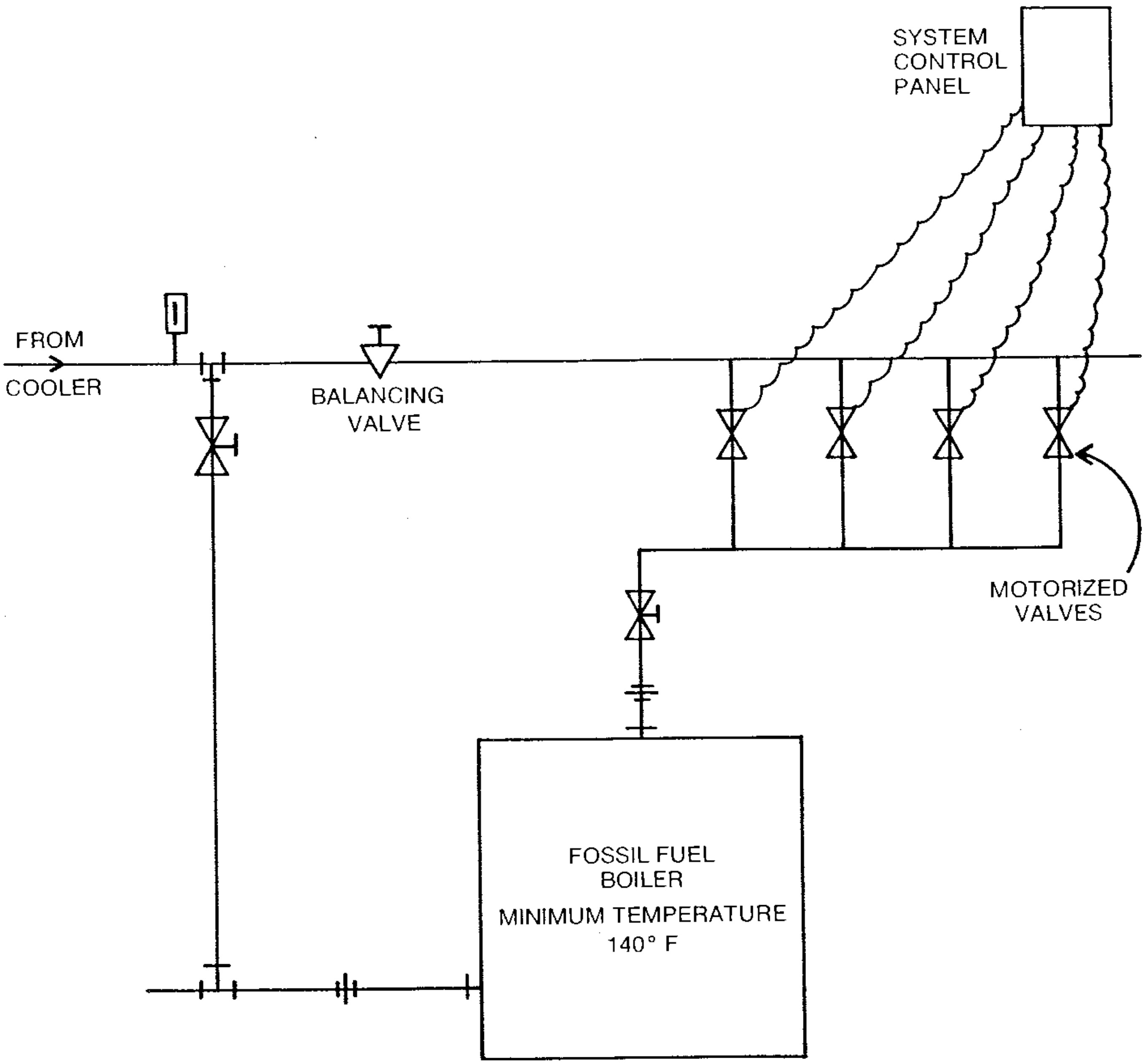
Figure 22

Figure 23

HEATER ARRANGEMENTS FOR HOT WATER BOILERS OIL OR GAS FIRED







STAGING USING A FOSSIL FUEL BOILER

When using a fossil fuel boiler to "meter" higher temperature water into the loop by opening smaller valves one at a time until desired loop temperature is met, system control panel will activate the individual valve.

H. PUMP SELECTION AND OPTION

Water pumps should be selected to deliver the necessary quantity of water against the total pressure of the system. Most heat pump applications will use centrifugal pumps. In a centrifugal pump, the impeller revolves and exerts a centrifugal force on the liquid in the case around the revolving impeller which is equal to the discharge pressure or head. A particular impeller has an inherent maximum pressure or head against which it can operate. In an open system if the actual pressure or head is higher than the one the pump is designed for, the impeller will merely churn the liquid; and in a closed system, the pump will reduce the GPM pumped until the friction loss drops to a head at which it can operate. Thus, proper pump selection is exceptionally important to the performance of the entire system.

Centrifugal pump performance is rated in feet of water head. When applying a pump for a given pressure, convert pounds pressure into equivalent feet head and select the pump accordingly. One pound water pressure is equal to 2.31 feet of head in a water column. Atmospheric pressure equals 14.7 lbs/sq. in. at sea level which, multiplied by 2.31 equals 33.9 feet.

This is the theoretical suction lift a pump should provide; however, there are various internal losses in a pump which reduce this theoretical suction lift. Check manufacturers' catalogs for maximum practical suction lifts.

The **total dynamic suction lift** in a pump is determined by two factors in an open system:

1. The vertical distance of the pump above the liquid (static suction lift).

2. Frictional resistance in the suction of the pump.

As in the case of the suction lift, the **total dynamic discharge head** in an open system is the sum of two or more factors:

1. Vertical distance of discharge above pump static discharge head.

2. Frictional resistance in the discharge pipe system.

3. Pressure, if any, required at end of discharge line.

The most practical prime mover to make this water circulate is a centrifugal pump. This section will deal with the selection and application of this type of pump.

The pump is selected on the same principles as any centrifugal pump applied to a hot water hydronic system. Selection is based on required flow, head and pump efficiency. The required flow has been determined to be 269.7 GPM. Efficiency is determined from the various pump manufacturing catalogs but usually should not be less than 70%. Head is the total resistance the pump must overcome to pump the water through the heat pumps, cooler, heater and relating piping, fittings and valves. The theoretical formula to estimate the hp required of the pump, prior to catalog selection . . .

$$\text{HP: } \frac{(\text{Head in ft.}) \times V\ (\text{volume in GPM}) \times 8.3}{33{,}000 \times (\text{pump efficiency})}$$

Proceed to select the pump as follows:

1. Heat Rejector — from the manufacturer's catalog at 269.7 GPM, read a 9 PSI drop × 2.31 = 20.8 feet.

2. Electric Heater — from the manufacturer's catalog, read a pressure drop of 6.0 feet.

3. Heat Pumps — note that the perimeter units and core units are piped on a two pipe loop. Therefore, the maximum pressure drop of any one of the units is the pressure drop which must be overcome by the pump.

From **Figure 14** of Section VII-C for the Series 801, Series 814 and Series V, where the GPM/unit and the resulting unit pressure drop are shown, it can be seen that the maximum pressure drop is 20.48 feet of head, occurring across the 814-036 unit.

4. Piping Losses — a complicated method can be used, as outlined in the ASHRAE Guide, by adding up all the individual sections of piping and calculating the drop through each section. However, there is an easier method . . .

Measure the longest run of piping required for the building, starting at the pump and continuing through the building, through the longest perimeter loop and the cooler, then back down through the building to the heater and pumps. In this particular example the longest run of piping is 350'. As a sound rule of thumb, add 50% for valves and fittings for a total equivalent length of 525 feet.

From **Figure 15** on piping sizing from Section VII-E for a flow of 269.7 GPM, a 5" main will produce a friction loss of .7 psi for 100 feet of pipe. Since all sections of branches from Section VII-E were sized for less, this number will be used as the maximum. Therefore, the total pipe loss can be calculated.

$$\frac{.7\text{ psi}}{100\text{ ft.}} \times \frac{2.31\text{ ft.}}{1\text{ psi}} \times 525\text{ ft.} = 8.50\text{ ft.}$$

We can now proceed to select the pump from the summary of losses as follows:

Heat Rejector	20.8 feet
Electric Heater	6.0 feet
Heat Pump	15.7 feet
Piping Losses	8.5 feet
Total	51.0 feet

Calculated Pump Horsepower:

$$HP = \frac{GPM \times Head \times 8.3}{33{,}000 \times efficiency}$$

$$HP = \frac{269.7 \times 51.0 \times 8.3}{33{,}000 \times .7} = 4.9$$

Based on this data, select a 5HP pump. Refer to pump manufacturer's catalog to verify final selection, size, rpm and HP.

Since the pump is the main part of the water system, it is highly recommended that a stand-by pump should be installed. Each pump should be sized to handle the full system GPM at the calculated head or pressure drop; and the stand-by pump should be energized automatically in case of failure of the operating pump. The two pumps could be alternated with a pump alternator panel described in the section on system controls.

The pump should operate continuously to keep the water circulating. Otherwise the individual heat pumps will malfunction. Cycling of the pump could only be considered during the summer periods on buildings which have long temperature shut down and unoccupied periods.

The importance of vibration isolation is stressed. Water, being incompressible, will transmit sound throughout the piping grid. Effective vibration isolation can be achieved by using flexible connectors on the suction and discharge side of the pump, and with vibration isolation equipment at the pumps and piping supports.

If the water system is a closed system, a tank should be incorporated in the water system to compensate for the expansion or contraction of the water if the temperature changes. For the temperature ranged utilized in the Heat Recovery System, 1½% of the total water volume is necessary.

It is important that no air be trapped in the system. An air separator and manual vents (installed at the highest point in the system) should be used. The expansion tank and airtrol or vent devices are used only on completely closed water circuit systems and are not used in an open cooling tower.

A good pump arrangement is shown in **Figure 24** and should have the following auxiliary equipment and arrangement . . .

1. Pumps piped in parallel arrangement for continuous operation, with one acting as a standby.

2. Each pump should have positive closure valves on both inlet and outlet for service.

3. Each pump should have pressure gauges on both inlet and outlet with snubbers to settle out surges.

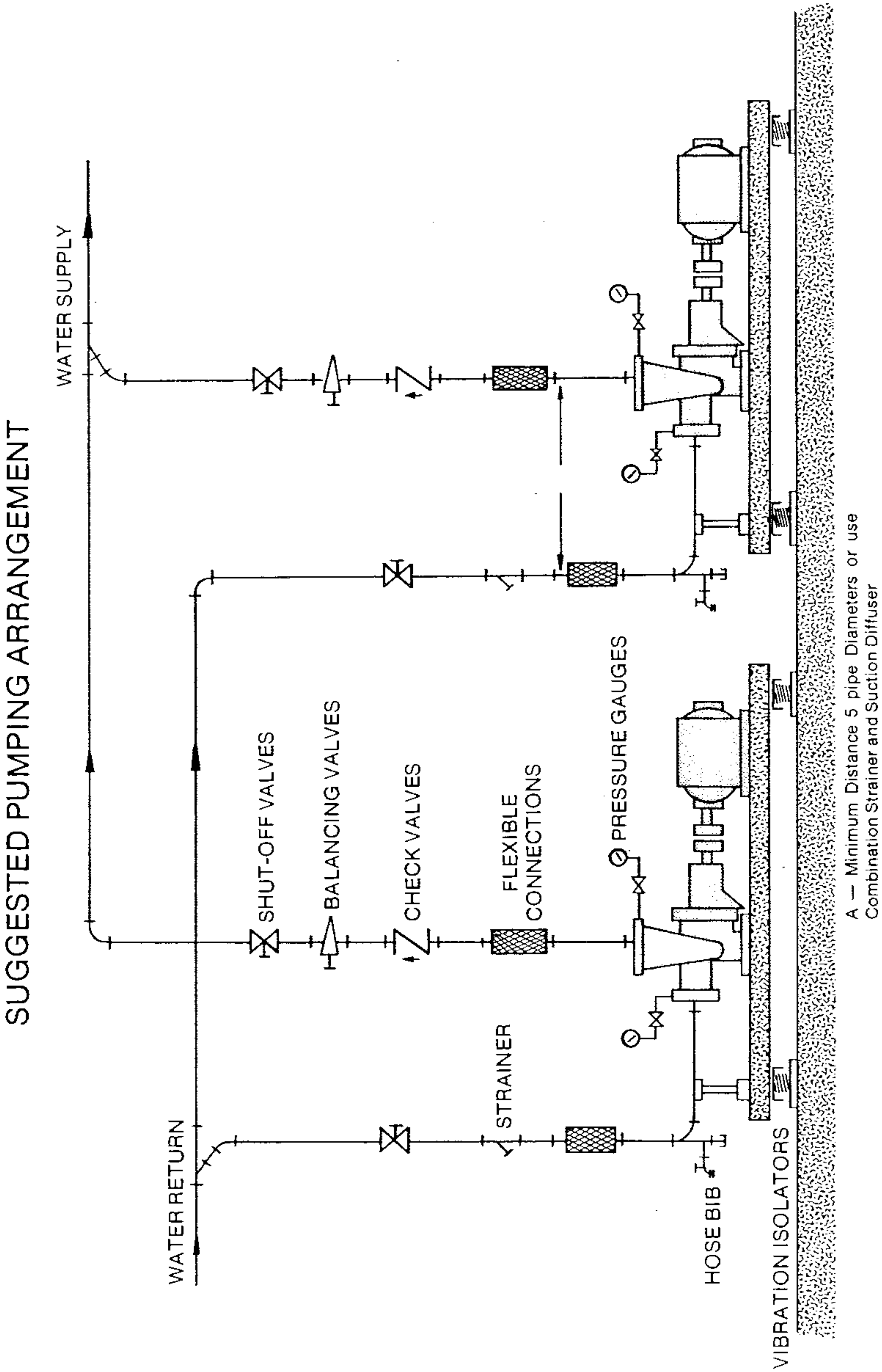
4. Each pump should have suction diffusers with strainers.

5. Each pump should have a combination balancing valve and check valve on discharge side of pump.

6. Pumps should be mounted on inertia pads or some form of vibration-eliminating devices.

7. Depending on pipe installation, flexible connections should be on the inlets and discharge lines of pumps.

Figure 24


SUGGESTED PUMPING ARRANGEMENT
WATER SUPPLY
WATER RETURN
SHUT-OFF VALVES
BALANCING VALVES
CHECK VALVES
FLEXIBLE CONNECTIONS
PRESSURE GAUGES
STRAINER
HOSE BIB
VIBRATION ISOLATORS
A — Minimum Distance 5 pipe Diameters or use Combination Strainer and Suction Diffuser

I. CONTROL SELECTIONS AND OPTIONS

Controls for a Heat Recovery System can be very simple. The objective is to provide the maximum amount of individual control with a minimum of complex equipment — and at the lowest possible first cost. Controls can be divided into four categories:

1. Individual Heat Pump Controls.
2. Controls to maintain the proper water temperature in the loop.
3. Unit safety controls.
4. Convenience controls or options.

1. Individual Heat Pump Controls

The perimeter console Series 801 unit is furnished with unit-mounted controls for individual control of heating and cooling by the occupant. This control consists of a manual changeover from heating to cooling and a unit-mounted thermostat to adjust the temperature control. The unit can be switched from heating to cooling and vice versa at anytime, year round.

Options:

a. Unit-mounted automatic changeover which contains an on-off switch and adjustable thermostat, allowing the unit to automatically switch from heating to cooling and vice versa to satisfy the thermostat setting.

b. Wall-mounted thermostat for manual changeover.

c. Wall-mounted thermostat for automatic changeover. Controls for the 814 and V consist of wall-mounted thermostat for either manual or automatic changeover control. In all cases, the controls are factory-wired. Only the wall thermostat applications require low voltage wiring between the unit and the thermostat. Additional unit options are available to control multiple units from a single thermostat for large space control. This arrangement is called Master-Slave and is shown in **Figure 25.**

2. Controls to Maintain the Proper Water Temperature in Loop

The Heat Recovery System operates in a water temperature range of 60° to 95°. Within these limits, no additional heat is required and none needs to be rejected. Whenever temperature falls below 60°, heat is required. Above 95° F, heat needs to be rejected. Therefore,the only necessary control is a device to turn on the heater or cooler as required. As a practical matter, however, the addition or rejection of heat begins in stages before these operating limits are reached.

The heater controls are normally built into the electric heater in the form of a rheostat or potentiometer which can be set to bring on stages of electric heat elements and turn them off as required. For oil or gas heaters, the control can be 2 or 3 way valves which open or close to admit hot water to mix with the loop water, to maintain a mixed leaving-water temperature. This is sensed by a thermostat located in the pipe at the point where mixed water leaves the heater.

Similar type controls are used on the hot water heat exchanger or steam converter. If gas-fired boilers are used, a solid state sequencing device can be installed to regulate the firing of boilers. In addition, there must be a cooling tower control to energize the cooler when heat must be rejected. The objective of this self-contained, pre-wired control panel is to provide loop water temperature control and to indicate malfunction both visually and audibly for ease of trouble-shooting. The specially designed control panel is necessary for controling the cooler and its auxiliary equipment, and for maintaining the loop water temperature between the limits of 60° and 95°. When these limits are exceeded by 5°, a loud alarm is automatically turned on. A sequence of events programmed into the panel in a system with a closed circuit cooler is outlined as follows:

80° Opens normally closed cooler damper on loop water temperature rise. Blowers and spray pump cannot operate until damper is open.

83° Starts the cooler spray pump for evaporative cooling. This setting, and the first stage blower setting, may be raised for increased operating economy in cold weather when the system has a high internal heat gain.

85° Starts the first stage cooler blower.

88° Starts the second stage cooler blower.

90° Starts the third stage cooler blower.

93° Starts the fourth stage cooler blower.

The no-flow control consists of either a pressure controller or flow controller mounted in the main water loop. In case both pumps should fail, or one fails to switch over to standby and no-flow occurs, an alarm is sounded and a no-flow light comes on.

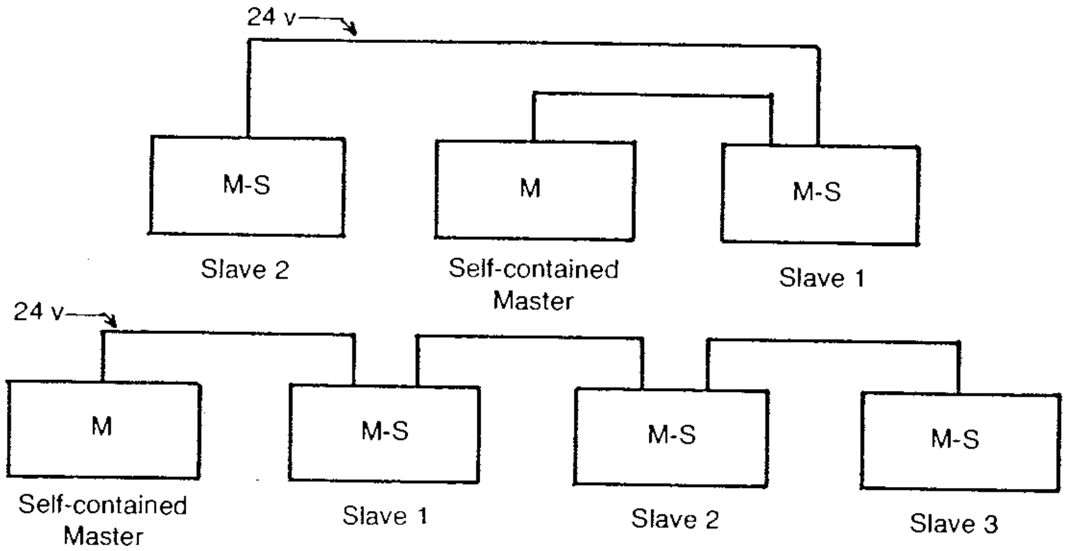
An outdoor thermostat can be supplied to lock out the cooler spray pump whenever the outside temperature reaches 35° F. A leak control can also be provided. A flow switch in the expansion tank will indicate a low water condition through a low water relay. Illustrated in **Figure 26** is a typical arrangement for cooler controls.

Figure 25

MASTER-SLAVE CONTROL ARRANGEMENTS

For use when multiple units are to be controlled from one unit on one thermostat.

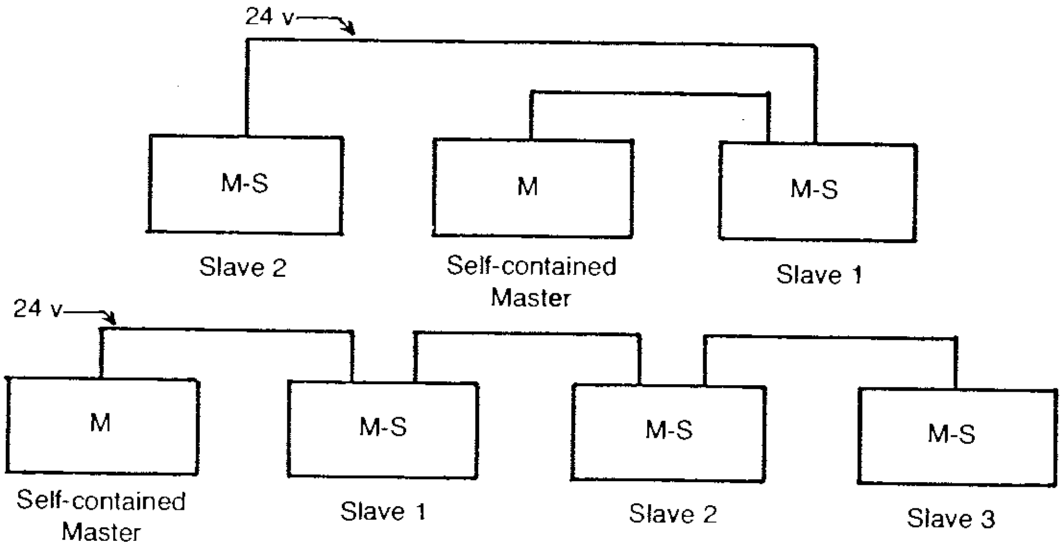
Wall Mounted Thermostat Arrangement Series #801



M = 24 v Master Terminal Board
S = 24 v Slave Terminal Board

Only 24 v wiring is shown. Each unit to have its own line voltage power supply.

Wall Mounted Thermostat Arrangement Vertical and Horizontal Series

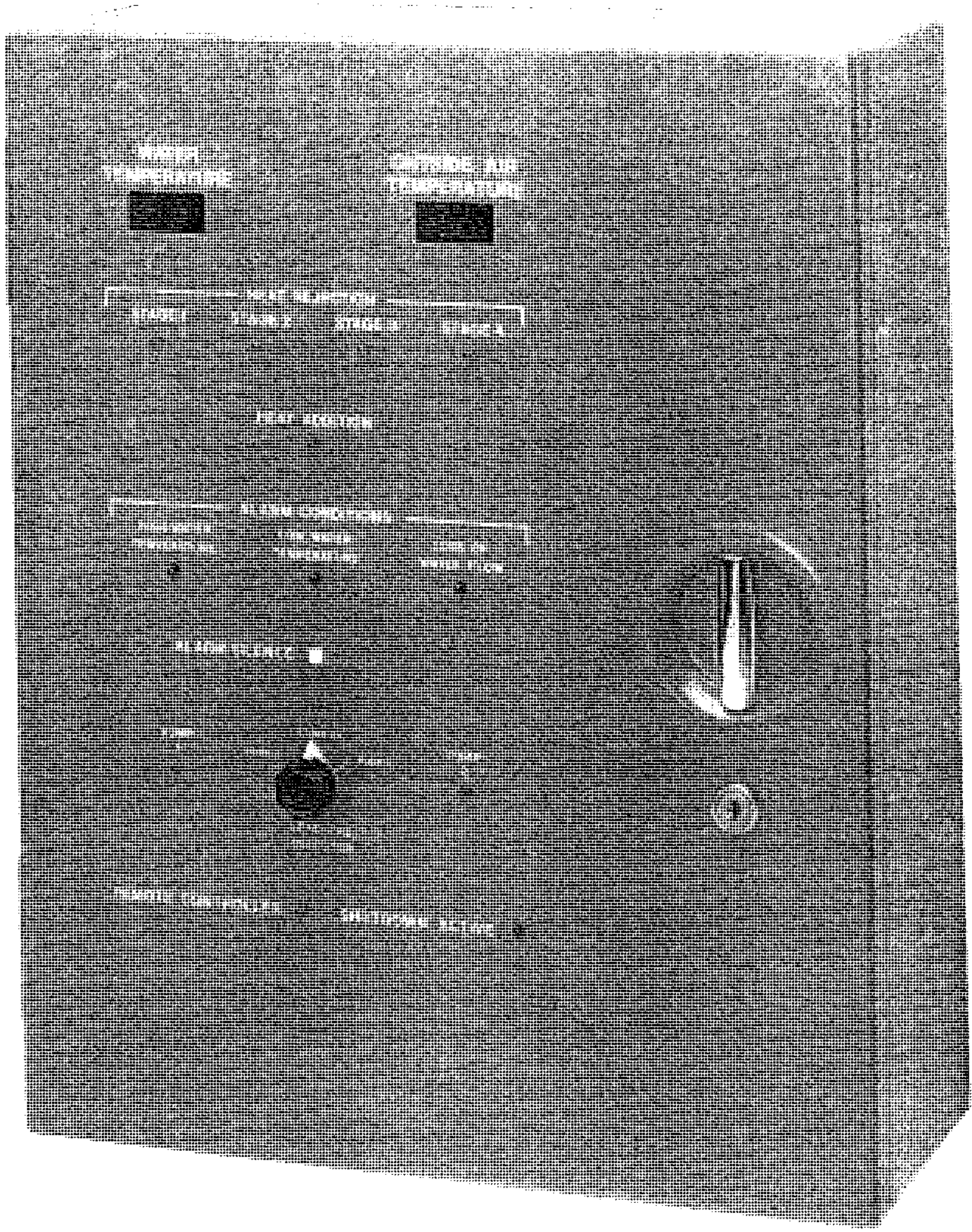


M = 24 v Master Terminal Board
S = 24 v Slave Terminal Board

Only 24 v wiring is shown. Each unit to have its own line voltage power supply.

Figure 26

MACS SERIES



3. Unit Safety Controls

In addition to the individual heat controls and system water control, each individual heat pump has built-in safety devices:

a. The Series 801 Console Units are equipped with high pressure cutouts and low water temperature of the manual-reset type, designed to protect the units. In addition, the compressors and fans contain built-in overload protection. Supplementary disconnects and circuit breakers can be added options.

b. The Series 814 and Series V contain electric-reset high and low pressure switches.* These are of the manual-reset type at the thermostat or panel board. In addition to these switches, the compressors and fans contain overload devices. Disconnects and circuit breakers should be installed to meet local codes às required.

*Small tonage units have low water temperature control.

c. The heaters or boilers normally contain built-in safety devices such as high temperature cutouts or override limit controls and should be specified.

d. The Heat Recovery System should always be furnished with two circulating pumps — one to be operational and one to be a stand-by. A safety device called a pump alternator should be supplied which will automatically start the stand-by pump in case of failure of the operating pump. This is an electrical device which will sense an electrical motor failure, switch over to the stand-by, sound an alarm, and indicate the other pump has failed. Each pump should be equipped with a check valve to prevent backflow when switchover occurs. The Climate Master alternator also allows a manual switchover as desired, to provide for servicing a pump, or to provide equalization of the operating hours on pumps and motors. This is included in the PSCP.

4. Convenience controls or options

The Heat Recovery System will operate as previously described with its own individual controls, water and pump controls with safeties. There are other optional controls which can be added for convenience or further operating economies.

a. Night set-back control with low limit — this type of control allows the units to be turned off by a central clock at night and on weekends, or during any unoccupied hours, and to be turned back on when desired. A low limit stat is required to override the building temperature below a predetermined level.

b. Off-hour use control — this control is normally used with the night set-back system. Through the use of an override timer, the tenant can reenergize the system for a number of hours by overriding the clock through the timer. This feature is important for usage of the building at night or during the unoccupied cycles. If the building owner wishes to bill a tenant for equipment usage during such periods, an hour counter can be added to provide the necessary basis for billing.

c. Warm-up cycle — this control actuates the fresh air dampers or fans through a return air stat to prevent cold outside air from entering the equipment until the return air or space temperature has been warmed to a preset temperature.

d. No-flow control — in case both pumps should fail, or the alternator not function properly, this control will electrically deenergize all of the Heat Pumps. In large buildings, this is a convenience control — otherwise each heat pump would have to be manually reset after a no-flow condition. The no-flow control has a single reset button allowing options of zones or floors for resetting.

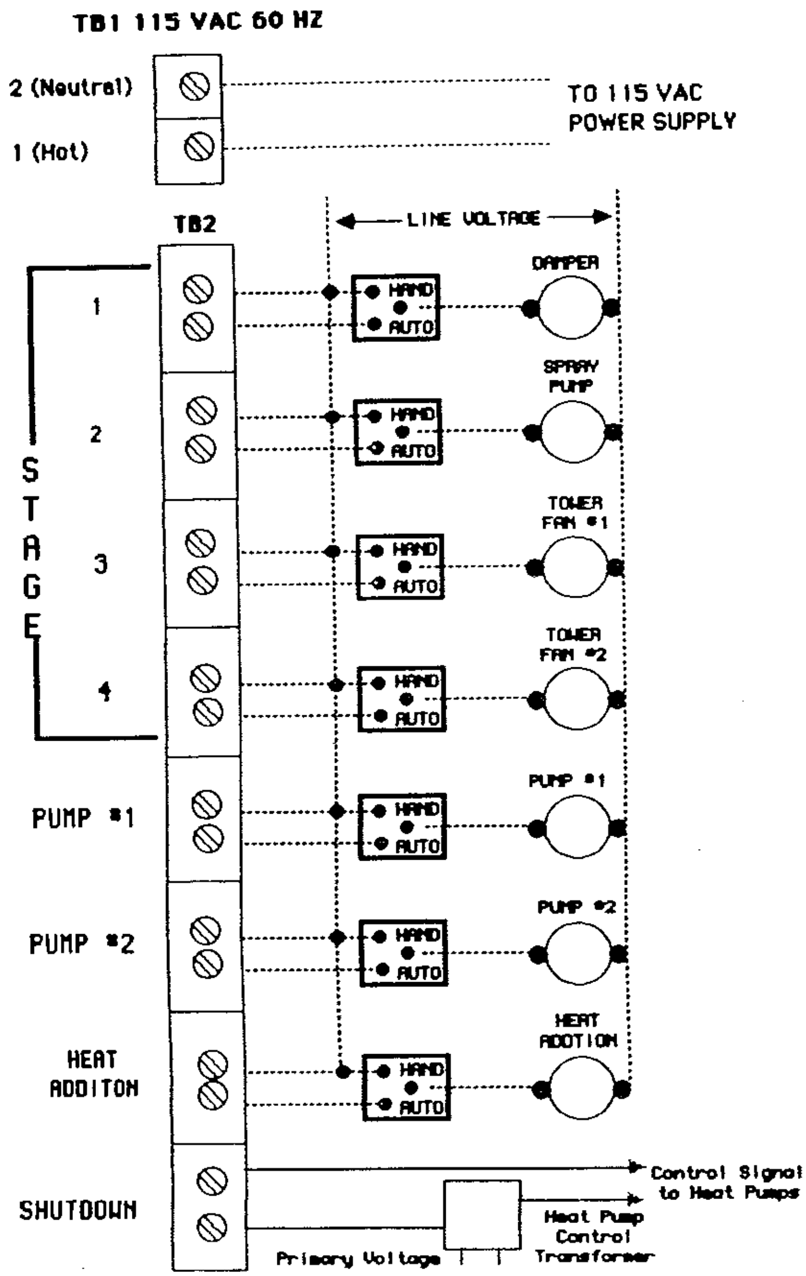
Figure 27
MACS

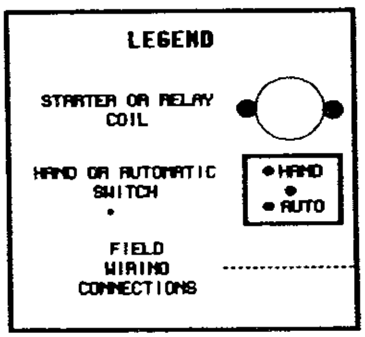
SUBMITTAL DATA

Typical Field Wiring For Closed Circuit Cooling Tower

WIRE SELECTION TABLE FOR STARTERS, RELAY COILS, ETC

WIRE FEET	SUPPLY VOLTAGE (VAC) 24	120	208	230	277	460	575
	MINIMUM WIRE GAUGE (AWG)						
1-249	18	18	18	18	18	18	18
250-499	16	18	18	18	18	18	18
500-999	14	16	16	16	16	18	18
1000-1499	12	14	14	14	14	18	18





Continuing engineering research results in steady improvements. Therefore, these specifications are subject to change without notice.

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ClimateMaster

J. VENTILATION

Building ventilation can be accomplished in several different ways in a Heat Recovery System. In general, it is advisable to maintain the building under a slight positive pressure — this minimizes air infiltration. The amount of ventilation or outside air required will vary due to occupancy, codes, usage, and other factors. ASHRAE Standard 90-75 generally establishes a rate of .15 cfm/ft² for office buildings.

Ventilation is usually accomplished with a combination of exhaust and supply fans. Positive pressure is obtained by sizing the exhaust system slightly less than the supply system. The total exhaust can be a combination of toilet exhaust, telephone equipment room exhaust, transformer room exhaust and general exhaust.

Outside air is usually ducted to the interior of the building through a central location or core where it is mixed with the return air and then ducted throughout the area. The outside air can be ducted direct to the units or to a room containing the units which is used as a plenum. The outside air inlet should contain dampers for control and balancing. The outside air duct may or may not need supply fans — depending upon the distance of the intake from the unit. In either case, means should be provided for closing the outside air inlet (via dampers or by stopping fans) to prevent outside air from entering during warm-up or during unoccupied cycles.

If humidification is desired, it can easily be added to the supply duct at these locations. The duct can either rise vertically through the building in low rise buildings, or horizontally per floor in high rise buildings. This air should be pre-heated and controlled where very cold temperatures are encountered. For proper operation of the heat recovery units, the return/outside air mix temperature should be above 60° F.

If the exhaust air is large and can be conveniently centralized near the intake air, an air-to-air heat exchanger should be given consideration for use in preheating the outside air in winter, and precooling the air in summer, to reduce operating costs. Depending upon the type of exchanger chosen, an efficiency of 70%-80% can be expected.

When ventilation cannot be fully obtained with a ducted system, the perimeter or console units can be equipped with outside air intakes consisting of a brick vent sleeve, grille and damper. The damper can either be motorized or manual. This type of control is adequate on a unitized basis but has some limitations. Manual dampers controlled by the occupant can be left open causing control problems. The small vent sets and resulting air intake can be affected by wind velocity and building stack effect. There is no way to temper this air, and this may result in oversizing the perimeter units. If this method of ventilation is used, it is advisable to use motorized dampers and wall-mounted thermostats.

K. SOLAR COLLECTION

Although they were not included in calculations for use in this example building, solar collectors are ideally suited for application with Heat Recovery Systems, and are convenient and economical to install. For these reasons, their use will become more prevalent in the future.

Their application with Heat Recovery Systems is especially favorable for three particular reasons:

1. Moderate Solar Collector Heating Requirement — the maximum capacity required of the solar collectors is not the total heat loss of the building, but rather only that portion which is needed to supplement the heat pumps. This would be the same capacity for which the electric heater in this example building was selected at 90KW, or a little over 300,000 BTUH. The heater would, of course, be retained in the system as a back-up.

2. Temperature Differential — the operation of the water loop system at temperatures between 60° and 95°, working with the range of practical discharge temperatures available from a collector, establishes a large log mean temperature differential for efficient collector utilization. Further, there is considerable opportunity for optimization of collector capacity with storage tank capacity since the larger the tank and the higher the stored water temperature, the greater is the number of hours the solar-collected heat can be used to eliminate or reduce the use of other energy sources.

Figure 13 illustrates a typical schematic using solar collectors and shows that only the storage tank, pumps, piping and controls to switch from the solar tank to the back-up heater when necessary, are required to complete the system.

In general, solar collectors in combination with water-to-air heat pumps are becoming economically feasible on residential and small commercial applications.

VIII. Economics

For each building application, there are several systems which can provide reasonable heating and cooling. But not all can do it equally well; and not all are equally economic. So a choice must be made among the competing systems which best fit the System Performance Criteria and the Economic Criteria established by the owner.

For a multi-room commercial office building with a significant core area, certain major System Performance Criteria are inherently established. For instance, it is established that the system must be able to cool the core area while simultaneously heating the perimeter areas in the winter-time. And since few tenants will accept perimeter offices that lack individual temperature control, this establishes that there will be many temperature control zones to be satisfied. A number of systems are thus eliminated from consideration.

Economic Criteria are obviously important. In the past, first cost was the primary criterion. More recently, scarcity of skilled maintenance labor, and especially, rising energy costs have made maintenance and operating costs a much higher proportion of the continuing costs of building ownership and operation. Thus, it has become increasingly important to analyze all the costs involved — first cost, operating costs, and maintenance costs. These are frequently analyzed in the form of a life-cycle cost in order to provide a balanced view of these costs.

For the example building, the System Performance Criteria set by the Owner were as follows:

1. Individual Perimeter Module Control, year round

2. Reasonable sub-divided Core Control, year round

3. Flexibility for partition layout changes

4. Proper outside air intake and exhaust for odors, smoke and comfort control

5. Acceptable sound levels

6. Minimum air pollution

The systems generally accepted as meeting these criteria are considered to be:

1. Water Source Heat Recovery System

2. Packaged Terminal Air Condioners with separate core system (PTAC)

3. Variable Air Volume (VAV)

4. Four-Pipe Fan Coil (4-Pipe)

5. Two-Pipe Fan Coil with Reheat (2-Pipe)

6. Induction

7. Double Duct

As mentioned earlier, not all these systems will meet the criteria to the same degree, so the general criteria are broken down into more specific points on which to make an objective evaluation of each of the systems; and, in order to provide a basis for measuring differences in degree, a numerical scale is established as follows:

1. Poor

2. Fair

3. Good

4. Very Good

5. Excellent

The system that scores the highest number of points would be most likely to satisfy all the Owner's criteria.

The evaluation is shown in **Figure 28** following.

Based upon the evaluation in **Figure 18**, the selections in order of preference would be:

1st — Water Source Heat Pump Heat Recovery System

2nd — Packaged Terminal Air Conditioners

3rd — Variable Air Volume

4th — Two-Pipe Fan Coil with Reheat

5th — Double Duct

6th — Four-Pipe Fan Coil

7th — Induction

Figure 28

PERFORMANCE EVALUATION

Criteria	Heat Recovery I	Thru-Wall PTAC II	VAV System III	4-Pipe IV	2-Pipe V	Inductor VI	Double Duct VII
Operating Costs	4	3	4	3	2	1	1
Ease of Installation	3	4	3	2	3	2	2
Individual Metering	3	4	1	1	1	1	1
Downtime in case of Component Failure	5	5	2	2	2	2	2
Maintenance Costs	3	3	2	2	2	3	2
Ease of Service	3	4	2	2	3	2	2
Economizer Cycle Available	1	1	4	1	1	3	4
Installation Flexibility	4	4	4	2	2	2	3
Noise	3	2	3	4	4	2	4
Installed Costs	4	5	3	2	4	1	1
Fresh Air Capability	2	2	4	2	2	4	4
Life Expectancy	3	2	4	4	4	4	4
Retrofitting Ease after Installation	4	2	4	2	2	1	2
Controls Simplicity	5	5	2	2	3	2	2
Operating, Engineering Costs	4	4	3	3	3	2	2
Design Ease	3	4	2	2	3	2	2
Room Floor Space Required	4	2	4	2	2	2	4
Mechanical Room Space Required	4	5	3	2	2	1	1
Ease of Start-up & Balancing	3	4	1	2	2	1	1
How Fast to Install	4	5	3	2	4	2	2
Load Diversity	5	3	4	3	2	2	3
Capacity Control	4	3	4	3	2	2	3
Air Circulation	3	2	4	3	3	4	4
Wintertime Humidity Control Options	2	2	3	2	2	3	3
Off-hour use Flexibility	4	4	2	2	2	1	1
	87	84	75	57	62	52	60

For a particular building, other factors can be included in the evaluation as appropriate.

On the basis of experience with various systems in the particular locale of the example building, further information on the Economic Criteria may be considered as follows:

First Cost:

Experience has shown that a well-installed Heat Recovery System in a multi-room type application will cost from $3.00 to $5.50 per square foot.

Maintenance Costs

Normally an operating engineer is not required, due to the simplicity of controls and equipment. An analysis has been made on about 10 office buildings equipped with heat pumps over the past 5 to 7 years and the average HVAC maintenance costs have been less than 10 cents per square foot. This number will be higher if a full-time maintenance man is assigned to the job — and will be disproportionate if the man is in charge of a small project versus a large one. In determining maintenance, the following should be considered:

1. Perimeter and Core unit filters should be changed 3 to 4 times a year.

2. V-belts checked on larger units.

3. Pump and tower bearings should be greased several times a year.

4. Controls should be checked periodically.

5. Components in units will be replaced only in case of failure, and can be changed in place.

6. Chassis should be removed for major repair only in case of refrigerant system failure; and can be shipped to repair depot for repair and returned. Spare units can keep tenant operating.

7. Cost of major repair to unit will probably not exceed $350.00.

Operating Costs

This area has been subject to prejudice and controversy due to the lack of information. In order to assure optimum operating costs prediction, a typical office building should be metered. Friedrich selected such a project in 1974 and installed meters. The building was occupied and the meters were recorded, starting in September 1975, and have been read every month for a full year. In the following is a Case History of the building, describing the building, system and meter arrangement. In the Summary can be seen the meter readings, and actual costs of the various components of the system. From this data, with similar criteria, operating costs can be predicted fairly accurately.

IX. Case History

Coats & Clark Building
Soundview Farms
Stamford, Connecticut

Building Description

Two story with partial lower level containing cafeteria and kitchen, mechanical elevator equipment and electrical vaults, telephone equipment and storage, and some general office areas.

The upper two stories are devoted to general executive office spaces in the perimeter and interior general office space areas.

Overall Area	= 56,580 square feet
Total Installation	= 332.5 tons of A/C
Lighting	= approximately 4 watts/ft^2
Glass	= tinted and insulated
Construction	= pre-cast concrete columns bar joist construction — steel truss with 4" concrete — sill height insulated panels

System Description

The Climate Master Heat Recovery System is an all-electric system utilizing an electric supplementary heater and a closed circuit evaporative cooler as the heat rejector. The system is connected with two circulating pumps — one operational and one standby.

The Heat Recovery System is a monoflow console perimeter arrangement with interior single package vertical and horizontal heat recovery units all interconnected into a common water supply and return system. The water loop is monitored with a Climate Master temperature control system.

The total equipment includes:

Heater

Dewey Shepard Model #270 BHW 4T8,270 KW, 480/3/60 with 8 step control.

Total KW installed: **270 KW**

Cooler

Baltimore Air Aircoil Closed Circuit Cooler Model #VI-100-3, 750 GPM, 90° to 10° at 75° WB; two 20HP, 480/3/60 fan motors, and one 3HP, 480/3/60 spray pump motor. Unit complete with discharge cones and closure dampers.

Also includes 7KW of electric sump heaters. Total KW installed: **50 KW**.

Perimeter Units

Climate Master 277/1/60 Console Units — one-pipe with monoflow tees and flexible hose connections, less cabinets for custom enclosures by others; automatic changeover controls:

Size 800-7	15 units	(7000 BTUH cool)
Size 800-9	42 units	(9000 BTUH cool)
Size 800-12	34 units	(12,000 BTUH cool)
Size 800-16	36 units	(16,000 BTUH cool)
	127 units	

Total nominal tons of refrigeration installed in perimeter: **122 tons**

Core Units

Climate Master Vertical and Horizontal 480/3/60 Units with remote thermostat automatic changeover control:

Size 1503	4 units	(15 tons ea.)
Size 1003	3 units	(10 tons ea.)
Size 803	1 unit	(7½ tons ea.)
Size 62	2 units	(5 tons ea.)
Size 33	1 unit	(3 tons ea.)

Total nominal tons of refrigeration installed on core areas: **110.5 tons**

System Water Control

Climate Master Package Control Center HR-1202A containing controls for cooler dampers, spray pump, fan blowers, high temperature and low temperature water limits, no-flow preassure switch, and alarm horn. also includes Climate Master pump alternator PA-120A to automatically switch over pumps in case of motor failure. Also includes no-flow relay panel to electrically de-energize all HVAC units in case of sustained no flow conditions.

Circulation Pumps

Two Weinman 25HP 1750 rpm 480/3/60 pumps — one operational, one stand-by. Due to higher pressure drops in the monoflow portion of the system, these pumps are approximately 25% higher horsepower than would normally be required.

System Operation

All perimeter units are individually controlled with unit-mounted automatic changeover controls. Units are installed behind metal custom enclosures on approximately 14' centers with generally one unit per individual office.

The core system consists of packaged units supplying air to designated interior spaces through a system of duct distribution. Each perimeter office is also connected with a supply outlet from the core for fresh air mixture.

The Core mechanical rooms act as a plenum with air being returned through the ceiling space. Fresh air is introduced into the plenum space and is controlled by motorized dampers.

Each zone is controlled with time clocks for the purpose of system shut-down at night and start-up in the morning and week-end shut-down. A low limit thermostat overrides the clock to re-energize the perimeter units in case of low temperature during shut-down.

A warm-up cycle keeps the fresh air closed until the return air control temperature has been reached. Each zone has a timer so that the zone can be re-energized to override the clock for tenant off-hour usage of the zone.

METERED ZONES AND EQUIPMENT

Meter #1 — 50KW

This meter is located in the lower level main mechanical room and meters the entire electrical usage of the building.

Meter #2 — 50KW

This meter is located in the lower level main mechanical room and meters the electrical energy used by the evaporative closed circuit cooler — BAC #VI-100-3 cooler 50KW installed.

Meter #3 — 270KW

This meter is located in the lower level main mechanical room and meters the electrical energy used by the supplementary heater — Dewey Shepard #270 BHW RT8 270KW installed.

Meter #4 — 23KW

This meter is located in the lower level air handling mechanical room southwest wing and meters:

Unit Designation	Model No.	No. of Units	Total Capacity
AC-1	1003	1	10 Tons
AC-2	1003	1	10 Tons
Perimeter	800-12	3	3 Tons
	Total		23 Tons

Meter #5 — 61KW

This meter is located on the 1st Floor level air handling mechanical room serving the northeast wing and meters:

Unit Designation	Model No.	No. of Units	Total Capacity
AC-5	803	1	7.5 Tons
AC-6	1503	15	15.0 Tons
AC-11	62	1	5.0 Tons
Perimeter	800-7	1	0.6 Tons
Perimeter	800-9	15	11.2 Tons
Perimeter	800-12	3	3.0 Tons
Perimeter	800-16	28	18.7 Tons
		Total	61.0 Tons

Meter #6-23 KW

This meter is located on the 1st Floor level, in the air handling mechanical room serving the southwest wing and meters:

AC-4 #1503 15 tons

Perimeter units	
3 #800-07 (7,000 BTU)	1.75 tons
13 #800-09 (9,000 BTU)	2.25 tons
6 #800-12 (12,000 BTU)	6.00 tons
6 #800-16 (16,000 BTU)	8.00 tons
	18.00 tons

TOTAL Tons: 23

Meter #7-63 KW

This meter is located on the 2nd Floor level, in the air handling mechanical room serving the northeast wing and meters:

AC- 9 #1503	15 tons
AC-10 #1003	10 tons
AC-13 # 33	2.75 tons

Perimeter Units	
6 #800-07 (7,000 BTU)	3.5 tons
10 #800-09 (9,000 BTU)	7.5 tons
11 #800-12 (12,000 BTU)	11.0 tons
10 #800-16 (16,000 BTU)	13.3 tons
	35.3 tons

TOTAL TONS: 63.05

Meter #8-45.5 KW

This meter is located on the 2nd Floor, in the air handling mechanical room serving the southwest wing and meters:

AC- 8 #1503 15 tons

AC-12 # 62 5 tons

Perimeter Units	
6 #800-07 (7,000 BTU)	3.5 tons
4 #800-09 (9,000 BTU)	3.0 tons
11 #800-12 (12,000 BTU)	11.0 tons
6 #800-16 (16,000 BTU)	8.0 tons
	25.5 tons

TOTAL Tons: 45.5 tons

NOTE: The circulating pump was not separately metered. The cost for pump operation can be determined by multiplying the KW draw by the operating hours times an average of 3.8 cents/KW. The operating hours will be 8760, since the pump runs 24 hours a day, 365 days a year.

CLIMATE MASTER HEAT RECOVERY SYSTEM

Electric Metering Cost Study for HVAC

Meter Readings from 9/29/75 thru 9/20/76

Total Eelctric Company Main Meter Readings (for period above)

- 1,293,840 KWH

KWH/ft.²

- $\frac{1{,}293{,}840 \text{ KWH}}{56{,}000 \text{ ft.}^2} = 23.1$ KWH/ft.²

Total Cost

- 1,293,840 KWH × 4¢/KWH = $51,753.00

Cost/ft.²

- $\frac{51{,}753.00}{56{,}000 \text{ ft.}^2}$ = 92¢/ft.² total electric

HVAC

Cooling Tower Meter Readings	40,900 KWH
Boiler (240 KW) Meter Readings	172,440 KWH
Pump (25 HP) Meter Readings	175,200 KWH
Heat Pump Zone Meter #4	46,040
Heat Pump Zone Meter #5	90,100
Heat Pump Zone Meter #6	70,770
Heat Pump Zone Meter #7	91,700
Heat Pump Zone Meter #8	60,350
Total Heat Pump A/C Readings	358,960 KHW
Total HVAC Readings	747,500 KWH

% of Total Building which is HVAC:

$\frac{747{,}500}{1{,}293{,}840} = 57.7\%$

Total Cost of HVAC:

57.7% x 92¢/ft.² = 53¢/ft.²

Cost of Operation of the Components of HVAC

Cooling Tower

$\frac{40{,}900 \text{ KWH}}{1{,}293{,}840 \text{ KWH}}$ = 3.2% x 92¢ = 2.9¢/ ft.²

Boiler

$\frac{172{,}440 \text{ KWH}}{1{,}293{,}840 \text{ KWH}}$ = 13.3% x 92¢ = 12.2¢/ ft.²

Pump*

$\frac{175{,}200 \text{ KWH}}{1{,}293{,}840 \text{ KWH}}$ = 13.5% x 92¢ = 12.4¢/ ft.²

Heat Pumps (A/C)

$\frac{358{,}960 \text{ KWH}}{1{,}293{,}840 \text{ KWH}}$ = 27.7% x 92¢ = 25.5¢/ ft.²

Total Cost of HVAC

$\frac{747{,}500 \text{ KWH}}{1{,}293{,}840 \text{ KWH}}$ = 57.7% x 92¢ = 53.0¢/ ft.²

HVAC Component Usage as a % of total HVAC

Cooling Tower $\frac{40{,}900 \text{ KWH}}{747{,}500 \text{ KWH}}$ = 5.5%

Boiler $\frac{172{,}440 \text{ KWH}}{747{,}500 \text{ KWH}}$ = 23.0%

Pump* $\frac{175{,}200 \text{ KWH}}{747{,}500 \text{ KWH}}$ = 23.5%

Heat Pumps $\frac{358{,}960 \text{ KWH}}{747{,}500 \text{ KWH}}$ = 48.0%

100.0%

*Due to the higher pressure drops in the monoflow portion of the system, these pumps have approximately 25% higher power consumption than would normally be required.

It is often possible to obtain operating cost data from local power companies for other systems installed in the area. Comparisons of this to various buildings using different systems will be helpful information. For example, such a comparison was made in a local community on all electric buildings using different types of HVAC systems . . . per the tabulation below:

Bldg.	System	KWH/ft.²
#1	All air central reheat	33.8
#2	Dual Duct	73.9
#3	VAV	42.9
#4	Water-air Heat Pump	25.9
#5	Water-air Heat Pump	28.2
#6	Water-air Heat Pump	28.2
#7	VAV	37.2
#8	Rooftop Air-Air Heat Pump	45.4
#9	Water-air Heat Pump	23.1

Naturally, this data will vary from location to location and is affected by many variables, but procurement of such data on a local basis will tend to eliminate the effect of some of the variables and serve as a guide in making computations and judgments.

X. Start-up Procedures and Trouble Shooting

The most important function in achieving the full benefit of the concept, design and installation of the Heat Recovery System is proper start-up procedure. Damage can be done to the system and units if this very simple yet systematic procedure is not followed. This section goes through a procedure and provides a final check list. It is not complex but failure to follow the directions can mean poor operation.

An Installation, Operation and Maintenance Manual is provided for each project.

Figure 29

System Start-Up

- Flush-clean and check for leaks
- Adjust water/air level in expansion tank
- Vent system thoroughly and check water make-up system
- Check all valves for proper position
- Test all control devices on tower, pumps and system safeties
- Check flow balance
- Adjust auxiliary systems such as ventilation air, etc.
- Systematically start and log each heat recovery unit operation

Unpacking and Inspection

Each Climate Master Heat Pump has been inspected, tested and operated at the factory by Quality Control and packed to arrive in good condition. However, rough handling by carrier can cause damage. Equipment is shipped F.O.B. factory with freight allowed. Therefore, claims for damage must be initiated by the receiver against the carrier.

Visible Damage

Report evidence of damage to the carrier's agent at once. Request inspection and a report. If the unit has been damaged to the extent that it must be returned to the factory, return via the same carrier, and file the necessary claims against the carrier.

Concealed Damage

Upon removing the carton, inspect each unit for concealed damage. If damage is found, follow same procedure outlined for visible damage.

Piping and Electric

All water and electric connections must be installed in accordance with applicable codes, regulations, and Climate Master instructions on piping, wiring and fusing.

Water Piping

CAUTION: For two pipe systems the water inlet and outlet to the condenser is clearly marked. Make sure system supply and return piping is connected accordingly. For one-pipe console system the unit is marked either Right or Left hand. The hand is determined by facing the unit. If the loop supply water enters the unit from the Right it is R.H. The opposite is L.H.

Condensate Piping

Condensate Piping must be properly trapped at each vertical or horizontal unit (trapping not required on console units).

CLEANING AND FLUSHING OF HEAT RECOVERY WATER SYSTEM

A. Circulation Start-up Before Cleaning and Flushing

1. After the piping system is complete, the HVAC contractor shall connect supply and return run-outs together at each heat pump location. Connection of supply and return run-outs shall be made up by contractor with short lengths of high pressure rubber hose and brass fittings per detail shown on plans. One fitting shall be swivel type to eliminate turning fitting in hose.

2. System shall be filled at city water make-up connection, with all air vents open. After filling, vents shall be closed.

3. Contractor shall start main pump. Vents shall be checked in sequence to bleed off any trapped air in order to assure circulation through all components of the system. Makeup water must be available to the system to replace the volume formerly occupied by the air which is bled off.

4. Contractor shall in turn energize supplemental heat source and set control to 90° F loop temperature. Power to all heat pumps and heat rejector motors must be off.

B. Cleaning and Flushing the Water Circulating System

1. Extreme care shall be exercised by the HVAC contractor to prevent dirt and other foreign matter from entering pipe or components of system during construction. Pipe stored on project shall have open ends capped and equipment shall have all openings fully protected. Before erection, each piece of pipe, fitting or valve shall be visually examined and all dirt removed.

2. With system filled, circulation established, trapped air vented and supplemental heater on, contractor shall check water thermometers installed at key points of system to determine that loop temperature is approximately 90° F. Any leaks in piping shall be repaired before proceeding. Drain at lowest point(s) of system shall be opened for initial flush and blowdown, making sure city water fill valves are set to make up water at same rate. Check pressure gauge at pump suction and manually adjust make-up to hold same steady positive pressure before and after opening drain valve. Flushing shall continue until water leaving open drain shows clean. In no case shall flushing period be less than two hours.

3. Supplemental heater and circulator pump shall be shut off. All drains and vents shall be opened to completely drain down the system. Short circuited supply and return run-outs at each heat pump shall now be reconnected permanently to respective inlets and outlets on each machine. Each condensate connection shall also be made up, making sure there is a steady pitch away from the unit. A commercial brand of Teflon ribbon tape pipe thread sealer shall be used when making up connections to minimize fouling of the tubes.

4. Close drains and refill system for operation under normal closed loop conditions. HVAC contractor shall add trisodium phosphate in an aqueous

solution to system, prepared in a proportion of 1 lb/50 gal of water in the system. After system is filled with this solution, the pump should be started, trapped air vented, and the supplemental heater set for 100° F (temporary setting for operating control and high limit). Solution shall circulate for approximately three hours. If Mechanical Engineer's representative deems it necessary, the cleaning operation shall be repeated.

5. System then shall be drained completely and refilled with fresh water.

6. After system has been completely cleaned as specified herein, it shall be tested by litmus paper or other dependable method and left on slightly alkaline side (PH 7.5). If system is still on acid side, cleaning by use of trisodium phosphate shall be repeated.

7. Supplemental heater operating control shall be reset to 70° F at this point and the high limit control reset to 80° F.

8. System Additives: "Stop-leak" compounds shall not be added to the system at any time. (Water treatment for corrosion and scale prevention are discussed on pages which follow).

Wiring

Line voltage wiring should be provided to each unit in accordance with specifications and applicable electrical codes. The supply voltage must be within plus 10% or minus 5% of nameplate rating on units marked 208/230 volts; and plus or minus 10% on units marked 115 volts, 265 volts, or 460 volts. Be sure to check nameplate ratings for proper voltage and full load amps.

Air Removal

After installation is complete and the system has been filled, leak tested, drained, flushed and cleaned, and refilled, all the air must be removed before starting the units. Air that is not removed can cause pockets in the condenser coils restricting the flow of water and resulting in damage to the unit.

CONSOLE START-UP PROCEDURE
Start-Up Procedure

A. Before beginning unit startup, be certain that:

1. The system flow has been established.

2. The system has been flushed and cleaned and filled.

3. The system and each unit's hand valves have been opened.

4. Each unit and the mains have been vented at least once.

5. Flow rate and balancing has been accomplished with the balancing valves and flow indicators to provide design flow conditions to each loop system. Proper flow rate to the heat pump system is very important since too little flow can cause improper operation and possible damage to the unit.

6. Bring the water temperature up to approximately 90°. Caution — the unit must not be used for temporary heat under any circumstances.

7. Flow and temperature alarm system as described herein has been checked and is operative.

8. The proper voltage to each unit has been verified and necessary electrical protections established.

B. With main pump on and system operating as above, continue as follows, return to the unit closest to the pump and proceed throughout as follows:

1. Close disconnect switch with "OFF" button depressed.

2. Turn the thermostat all the way clockwise to maximum cool position.

3. Depress the heat button which will allow the fans to come on with compressor off — if fans do not operate, recheck the power and refer to trouble shooting chart in appendix.

4. Now turn the thermostat slowly counterclockwise to "warmer" until the compressor comes on. Leave in this position and check for heat output.

5. In the heat position, vent the unit for elimination of additional air.

6. Allow to run in heat position to verify compressor operation.

7. Depress the cool button LO and the compressor will go off and fans continue to run.

8. Turn thermostat clockwise until the compressor comes on cooling and let it run in this position to verify cooling.

9. After each of these cycles the reversing valve will change position. This can be detected by its characteristic "swooshing" sound.

10. If water noise is heard it means there is still air in the system which should be removed.

11. By hand you can feel the water inlet and outlet pipes to the condenser and a temperature differential should be felt indicating proper operation.

12. If in any of the above procedures the unit malfunctions, refer to the "trouble shooting" chart in the appendix.

13. Check for any vibrations, unusual noises or water leaks.

14. After being satisfied the unit operates in all positions, it should be turned off and the procedure repeated on the next unit until all units have been checked and started.

C. Upon satisfactory completion of the above, the system is ready to run. All units can now be normally started and set on either heat or cool depending on climatic conditions. Make sure the system controls which control the water temperature are operative, such as:

1. Controls set to energize heater to prevent water from going below 60°.

2. Controls set to energize tower to prevent water from going above 105°.

3. Set operating range between 60° to 95°.

4. Again check alarm system on temperature to sound above 105° and below 55°, and to sound when flow fails.

HORIZONTAL AND VERTICAL UNIT START-UP PROCEDURE

A. Installation

1. Check that correct size unit is installed per plans and specifications.

2. The unit should be installed per recommendations.

B. Pre-Operational Checks and Requirements

1. The correct voltage is wired to the unit.

2. Check thermostat and low voltage wiring.

3. Correct circuit breaker or fuse size is used on each unit.

4. The water loop system is flushed, cleaned and purged of air and all foreign material.

5. The water system temperatures and flow rates to all the units are adequate.

6. The condensate lines are individually trapped and clean.

7. All electrical connections are tight.

8. The unit is adequately grounded.

9. All panels are installed.

10. The filters are installed and clean.

C. Operational Checks

1. The thermostat should be set as follows:

FAN — ON
SYSTEM — OFF
TEMP SETTING — ANY

Check for blower operation, adequate air flow balance air distribution system if necessary.

2. Set the thermostat as follows:

FAN — AUTO
SYSTEM — COOLING
TEMP SETTING — LOW (MIN.)

Unit should distribute cold air at outlets. If necessary, balance the water flow rate.

Raise the temperature setting to make sure that the compressor and fan cease operation. This should produce a check at the cut-off point to ensure correct thermostat installation and calibration.

3. Check the lock-out circuit operation by allowing the unit to operate on cooling mode and shutting off the water supply.

The unit should cease operation within a few minutes, due to the high pressure safety switch.

Reset the circuit by turning system switch on thermostat to "off" and turning on the water supply.

4. Set the thermostat as follows:

D. FAN — ON
SYSTEM — HEAT
TEMP SETTING — HIGH (MAX.)

The unit should deliver hot air at the outlets.

IF ANY OF THE OPERATIONAL CHECKS FAIL, PLEASE REFER TO THE TROUBLE SHOOTING CHART IN THE INSTALLATION, OPERATION AND MAINTENANCE MANUAL.

Access Caution

Climate Master heat pumps are designed to make regular inspection and preventive maintenance easy to perform, and to provide adequate access for parts or components replacement if this should become necessary.

Do not defeat this accessibility by blocking access panels, service panels or slide-out chassis with water piping, condensate piping, electrical conduit, doors, or panels. For ceiling units, access panels must be large enough to remove the entire unit if necessary.

For units located in closets, the doors must be large enough for removal of components or the entire unit.

Water Treatment Caution

In the closed loop system, after the initial cleaning, the final fill should be checked and neutralized with a one-shot treatment if necessary. This water should not require further treatment unless a leak occurs and refilling is necessary. This water should be checked from time to time, however, as a precaution.

Very probably the water in the Heat Rejector Sump will have to be treated on a continuous basis due to evaporation.

If an open cooling tower is employed, the water is continually exposed to the Heat Pump units. In this case, extreme caution should be taken to insure proper filtration and treatment. A preventive maintenance program is very important to insure proper water conditions and to prevent corrosion and fouling of individual heat pumps.

Start-up Caution

The Climate Master units are designed to operate at a minimum of 60° air and water temperature with normal flow rates.

If it is necessary to start the unit on heating at ambient temperatures below 60° F, it will be necessary to have the water temperature entering the unit at 75°-80° F, but not to exceed 80° F because of overloading the refrigerant system.

XI. Troubleshooting

COMPLAINT	POSSIBLE CAUSE	CHECKS AND CORRECTIONS
Unit vibrates or rattles.	Discharge or suction tube hitting metal surface	Bend and adjust for clearance where hitting
	Loose or bent blower	Tighten or replace blower
	Blower motor out of alignment, bent shaft or loose on mounting	Check alignment and tighten mounting. Replace motor if shaft is bent.
Water drips from unit	Unit not level or pitched correctly	Level unit
	Condensate drain line kinked or plugged	Clean condensate drain
Noisy blower operation	Blower hitting	Check blower, adjust for clearance
	Bent blower	Check and replace blower
	Loose blower on shaft	Check and tighten
Unit operates, not cooling properly	Clogged air filter	Check filter. Clean or replace if found too dirty.
	Water flow through condenser restricted or stopped	Check condenser flow.
	Defective compressor or refrigerant leak	If compressor runs but the evaporator does not cool, it would indicate either a defective compressor or loss of refrigerant charge.
Evaporator ices over	Clogged air filter	Check filter. Clean or replace if found too dirty.
	Evaporator blower motor tripping off on overload	Check for overheated evaporator blower motor and tripped overload. Replace motor if necessary.
	Unit operating at too low room temperature	If room temperature drops below 55° F the evaporator may ice over
	Unit operates at too low water temperature	When unit operates when water too cold it may ice over
Unit will not work on "Heating"	Defective thermostat	If motor works in other positions and thermostat, klixon, etc. are O.K., check switch. Replace if found defective.
	Clogged or dirty filter	Check filter. Clean or replace if found too dirty.
	Thermostat improperly set	Is it below room temperature? Check thermostat setting.
	Defective thermostat	Check thermostat operation. Replace if found defective.
	Incorrect wiring	Check for broken, loose or incorrect wires.
	Evaporator motor defective	Check evaporator motor in one of the other switch positions. If it does not work check for open overload. If motor is not overheated replace it.

COMPLAINT	POSSIBLE CAUSE	CHECKS AND CORRECTION
Entire Unit does not run	Blown fuse	Replace fuse or reset circuit breaker. (check for correct fuse)
	Broken or loose wires	Replace or tighten the wires
	Voltage supply low	If voltage is below minimum voltage specified on dataplate, contact local power company.
	Low voltage circuit	Check 24 volt transformer for burnout or voltage less than 18 volts.
	Thermostat	Set thermostat on "COOL" and lowest temperature setting, unit should run. Set thermostat on "HEAT" and highest temperature setting, unit does run. Set fan on "RUN", fan should run. If unit should not run in all three cases, the thermostat could be wired incorrectly or faulty. To ensure faulty or miswired thermostat, disconnect thermostat wires at unit and jumper between "R," "Y," "G," and "W" terminals and units should run. Replace T-stat with correct T-stat only. A substitute may not work properly.
Blower runs but compressor does not	Voltage supply low	If voltage is below minimum voltage specified on the dataplate, contact local power company.
	Thermostat	Check setting, calibration and wiring
	Wiring	Check for loose or broken wires at compressor, capacitor or contactor
	High or low pressure controls	The unit could be off on the high or low pressure cut out control. Reset the thermostat to "OFF." After a few minutes turn to "COOL." If the compressor runs, unit was off on high or low pressure (see complaints for possible causes). If the unit still fails to run, check for faulty pressure switch by jumping the high and low pressure controls individually.
	Defective lockout relay	Stuck open, does not reset when power is turned off.
	Defective capacitor	Check capacitor, if defective remove, replace and rewire correctly
	Seized compressor	Try an auxiliary capacitor in parallel with the run capacitor momentarily. If the compressor starts but the problem recurs on starting, install an auxiliary start kit. The hard-start kit is comprised of a recommended start relay and correctly sized capacitor. If the compressor still does not start, replace the compressor.

COMPLAINT	POSSIBLE CAUSE	CHECKS AND CORRECTION
Blower operates but compressor does not	Compressor overload open	In all cases an "external" or "internal" temperature sensitive compressor overload is used. If the compressor dome is too hot to touch, the overload will not reset until the compressor cools down. If the compressor is cool and the overload does not reset, there may be a defective or open overload. If the overload is external, replace the overload, otherwise replace the compressor.
	Compressor motor grounded	Internal winding grounded to the compressor shell. Replace the compressor. If compressor burnout, install filter dryer at suction line.
	Compressor windings open	Check continuity of the compressor windings with an ohmmeter. If the windings are open, replace the compressor.
Unit off on high pressure cut-out control	Discharge pressure too high	On COOLING Cycle: Lack of or inadequate water flow. Entering water too warm. Scaled or plugged condenser. On HEATING Cycle: Lack of, or inadequate, air flow. Entering air too hot. Blower inoperative, clogged filter or coil, restrictions in duct work.
	Refrigerant charge	The unit is overcharged with refrigerant. Bleed off some charge or evacuate and recharge with specified amount of R-22.
	Defective high pressure switch	Stuck open, does not reset, or has defective calibration. A replacement switch is available that attaches to the service port. When it is necessary to replace either of the pressure switches or reversing valve, wrap them with a wet cloth and direct the heat away. Excessive heat can damage them.
Unit off on low pressure cut-out control	Suction pressure too low	On COOLING Cycle: Lack of, or inadequate, air flow. If belt drive, check belt. Entering air too cold. Blower inoperative, clogged filter or coil, restrictions in ductwork. On HEATING Cycle: Lack of, or inadequate, water flow. Entering water too cold. Scaled or plugged condenser. When installed in an unconditioned space, (such as a garage) the unit may not start in cool weather, (approximately 50° F). In this case, it may be necessary to start the unit on cooling in cool weather for three to five minutes, then shut off and turn to heat, after one minute shut down. (It may be necessary to repeat this procedure several times, especially when a crankcase heater is not used).

COMPLAINT	POSSIBLE CAUSE	CHECKS AND CORRECTION
Unit off on low pressure cut-out control	Refrigerant charge	The unit is low in charge of refrigerant. Locate leaks, repair, evacuate and recharge with specified amount of R-22.
	Defective low pressure switch	Stuck open, does not reset or has defective calibration. A replacement switch is available that attaches to the service port. When it is necessary to replace the pressure switch wrap it with a wet cloth and direct the heat away, excessive heat can damage the pressure switch.
Unit short cycles	Thermostat	The differential is set too close in the thermostat. Readjust heat anticipator.
	Wiring and controls	Loose connections in the wiring, or control contactors defective.
	Compressor overload	Defective compressor overload, check and replace if necessary. If the compressor runs too hot it may be due to a deficient refrigerant charge.
	Thermostat	Improperly located thermostat (eg. near kitchen, sensing inaccurately the comfort level in living areas).
Insufficient cooling or heating	Unit undersized	Recalculate heat gains or losses for space to be conditioned. If excessive, rectify by adding insulation, shading, etc.
	Loss of conditioned air by leaks	Check for leaks in ductwork or introduction of ambient air through doors and windows.
	Thermostat	Improperly located thermostat (eg. near kitchen sensing inaccurately the comfort level in living areas).
	Airflow	Lack of adequate air flow or improper distribution of air. Check the belt tension or duct sizing. Check the filter, it should be inspected every three months and changed if dirty.
	Refrigerant charge	Low on refrigerant charge causing inefficient operation.
	Blower runs backwards	Reverse the (2) Blower Motor capacitor leads.
	Water	Lack of sufficient pressure, temperature and/or quantity of water. Possible scaling in condenser, (refer to cleaning and descaling methods).
	Compressor	Check for defective compressor. If discharge pressure is too low and suction pressure too high, compressor is not pumping properly. Replace compressor.

COMPLAINT	POSSIBLE CAUSE	CHECKS AND CORRECTION
Insufficient cooling or heating	Reversing valve	Defective reversing valve creating bypass of refrigerant from discharge to suction side of compressor. When it is necessary to replace the reversing valve, wrap it with a wet cloth and direct the heat away. Excessive heat can damage the valve.
	Operating pressure	Incorrect operating pressure (See chart).
	Refrigerant system	Check strainer and capillary tubes for possible restrictions to flow of refrigerant. The refrigerant system may be contaminated with moisture, non-condensibles and particles. Dehydrate, evacuate and recharge the system.
Noisy operation	Compressor	Make sure the compressor is not in direct contact with the base or sides of the cabinet. The hold-down bolts used for shipping should be loosened so that the compressor is floating freely on its isolator mounts. Excessive noise will occur if the compressor has a broken valve or loose discharge tube. Replace the compressor.
	Blower and blower motor	Blower wheel hitting the casing. Adjust for clearance and alignment. Bent blower: check and replace if damaged. Loose blower wheel on shaft: check and tighten. Defective Bearings: check and replace. It is good practice to inspect for belt wear and tension at this time. Correct belt tension is for the motor to be resting by its weight on the belt. If the belt is excessively tight there will be excessive heat generated in the bearings and ultimate failure.
	Contactors	A "clattering" or "humming" noise in the contactor could be due to control voltage less than 18 volts. Check for low supply voltage, low transformer output or extra long runs of thermostat wires. If the contactor contacts are pitted or corroded or coil is defective, repair or replace.
	Rattles and vibrations	Check for loose screws, panels or internal components. Tighten and secure. Copper piping could be hitting the metal surfaces. Carefully readjust by bending slightly.
	Airborne noises and other sounds	Undersized ductwork will cause high airflow velocities and noisy operation. Excessive water through the water-cooled heat exchanger will cause a rattling sound. Throttle back on the water flow ensuring adequate flow for good operation but eliminating the noise.
	Water	Reduce water pressure to below 35lbs. if a Dole Water Valve is used.

COMPLAINT	POSSIBLE CAUSE	CHECKS AND CORRECTION
Water leak	Plugged condensate drain or machine out of level	Condensate drains pick up dirt or algae which can grow, causing the drain outlet to clog and condensate to overflow. Inspect and clean. Check level of the unit and adjust.
Unit heats only	Reversing valve does not shift.	The solenoid valve is energized due to miswiring at the unit or the thermostat. The valve is stuck. The thermostat is in the cool position.

XII. Operating Pressures and Temperatures

The Climate Master Heat Pump is a factory charged unit. However, in cases of service or replacement of major components it will be necessry to recharge the unit. Prior to recharging the system the following steps are recommended:

1. Pressure test with dry nitrogen. Locate and repair all leaks.

2. Charge with several ounces of Refrigerant 22.

3. Use a good vacuum pump and evacuate system to 500 microns vacuum or equivalent (29.9 inches of mercury vacuum).

4. Charge the unit with the quantity in ounces of Refrigerant 22 specified on the dataplate. Do not attempt to charge the unit by running the machine and measuring the ampere draw to full load conditions.

There are cases when a particular system will have to be charged in accordance with pressures.

There are many variables (airflow, air temperatures) in an air-conditioning system that will affect operating refrigerant pressures and temperatures. The chart below shows approximate conditions and is based on airflow at the rated CFM.

Cooling Cycle
Range of Approximate Operating Pressures (PSIG)*

Air in (°F)	LEAVING WATER TEMPERATURE (°F)					
	85° F		95° F		105° F	
	Suction	Discharge	Suction	Discharge	Suction	Discharge
75	66-70	190-210	68-74	220-240	70-76	240-260
80	68-72	195-215	70-76	220-240	72-78	245-265
85	70-74	200-220	74-78	220-240	76-80	250-270

Heating Cycle
Range of Approximate Operating Pressures (PSIG)*

Air in °F	WATER TEMPERATURES °F Entering	WATER TEMPERATURES °F Leaving	Discharge Pressure (PSIG)
70°	60°	53°	210-230
	70°	63°	240-260
	80°	73°	280-300
75°	60°	53°	230-250
	70°	63°	250-270
	80°	73°	290-320

*Variances from these operating pressures may occur from machine to machine and model to model.

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Continuing engineering research results in steady improvement Therefore, these specifications are subject to change without notice

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